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Articles

Property Rights and the Political Economy of Resource Scarcity

Emery N. Castle

Changes in resource availability place property rights under stress. Major policy issues exist with respect to rights to land, water, and the ocean fishery. Sometimes these policy issues are confronted in the context of structural changes in property rights, that is, by changing the relationship among those who hold rights both within the private or between the public and private sector. In some instances, changes in resource availability may trigger macro policies designed to affect the distribution of income, employment, or inflation. These macro policies typically also have an indirect but very real effect on property rights.

Key words: economic rent, jurisdictional resource conflict, policy, property rights, redefinition.

In 1963 Barnett and Morse, in a most influential book, argued that resource scarcity in the classic sense was not a significant economic problem, while recognizing that impaired environmental quality might result from the rapid utilization of natural resources. Economists generally have agreed with Barnett and Morse. When the food and energy supply-demand situation shifted abruptly in the early 1970s, there were few resource economists and little analysis that could be drawn upon for policy guidance.

In the context of historical perspective, there has been a relatively short time for the modern industrial state to accumulate experience concerning the utilization of resources, and the Barnett-Morse analysis exhausted the available data for the United States when it was published. Whether or not history will serve as a reliable guide to the future depends on the pattern of consumption followed and the availability of substitutes in production. [illegible] correct conclusions are to be drawn [illegible] data, they must be interpreted in the [illegible] of the adaptive capacity of social processes. This is a subject about which we know very little (Dunn).

The industrialized world's appetite for transforming huge quantities of natural resources need not be documented here. The entire globe is involved in establishing the demand and supply relationship for many materials. Short-run shifts in either d[illegible]and or supply for certain materials can result i[illegible]ere adjustments in resource use with[illegible] econ-omy. Furthermore, significant transfers of wealth within and among economies can be triggered by these changing demand and supply conditions. The resource shortage need not be of permanent nature for the consequences to be realized over a relatively long period.

Macro adjustments to changing conditions of resource availability have been analyzed by Fried and Schultze. Their study attempts to ascertain the effects on the world economy of higher oil prices that developed early in this decade. It reveals the role of relative prices in minimizing the long-run economic costs of higher oil prices, but it also recognizes that problems are created by flexible oil prices necessary for long-run cost minimization. They say that "two problems arising out of the oil crisis provide real grounds for concern: the short-run difficulty of managing demand so as to avoid additional unemployment and inflation brought on by the shock of a large and sudden increase in oil prices and the tendency of higher oil import costs and an oil-induced

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[illegible]r is heavily in the debt of his colleague Edgar S. Dunn, [illegible]h that is of value in this paper. Richard N. Boisvert, [illegible]imyer, and Charles J. Hitch made valuable suggestions on content and organization. Some of the ideas presented have been tested in seminars at Kansas State University, Virginia Polytechnic Institute and State University, the University of Wisconsin, and the Natural Resources Economic Division, Economic Research Service, United States Department of Agriculture.

world recession to impose disproportionately large costs on the non-oil developing countries" (p. 56).

Thus, important long-run adjustments can be prevented by policies that are designed to minimize short-run impacts affecting employment, the general price level, and income transfer. Changed resource availability will place all institutions that influence resource use and income distribution under stress, beginning in a capitalistic economy with property rights.

Property rights are defined in the law and serve as rules governing the utilization and transfer of rights to wealth. In the absence of rule changes, or structural modification of property rights, the market for property rights will operate. Our ability to predict performance of these markets will depend on our ability to identify correctly those market right attributes which are relevant in decision-making in the economic system. However, the consequences of reliance on the market are such that other measures are often utilized. These "other measures" are of two general types.

One policy type is concerned with rule changes governing and defining property. A redefinition of rights, which changes the relationship among those who hold rights either within the private sector or between the public and private sector, may be considered a structural modification of rights. The net effect of land-use planning, zoning, and environmental protection often is a structural modification of property rights (Moss).

The other policy type is of an indirect nature. The political propensities of democratic capitalism, the distribution of market and political power among interest groups, and the uneven impact of monetary and fiscal policy mask and shift the costs of changing resource availability. For example, price policy with respect to agriculture and energy provide a marked contrast. From 1971 to 1973 real prices received by farmers increased approximately 42%. During that same period real gasoline prices decreased about 3%. Except for imported crude, other energy prices reflected comparative stability during this period. The effect of indirect policies on property rights are significant and real but are difficult to specify.

This paper has the following objectives: (*a*) to demonstrate that pressure on property rights stems from public policies followed as well as from changes in the supply and demand for natural resources; (*b*) to establish the political and economic conditions that must prevail if structural reassignment of property rights between the private and public sectors is to occur; (*c*) to evaluate the capacity of property rights to serve society in the face of changing conditions of resource availability; and (*d*) to call attention to the macro, as well as the micro, consequences of structural changes in property rights.

The paper is not addressed to resource adequacy, either for priced or non-priced natural resources, in a long-run or ultimate sense. While long-run resource availability deserves to be monitored and studied, a more important set of policy problems centers around the integration of short- and long-run objectives. It does not matter whether resources are available in a long-run sense if institutional rigidities prevent supply response from occurring or substitutes from being developed.

The market-failure body of theory, stemming from Pigou and articulated by Bator and others (Pigou, Bator, Castle 1965), has come to dominate much of the literature of resource economics but is inadequate for the above task. It needs to be supplemented by economic analysis of particular public policies and a modicum of political science and the law.

The Concepts

Property Rights, Externalities, and the Analysis of Institutions

Property rights have long been recognized as important to the functioning of an enterprise system (Meade). During the past two decades interest in the subject has flourished, largely because of the seminal work of Coase and others who have attempted to provide an analytic base for the study of property rights and economic decisions (Coase, Demsetz 1964, 1966, 1967). The literature of Coase and Demsetz has been extended and perfected by Mishan, Dolbear, Kneese (1971), and Randall.

Cheung argues that the term "externality" should be abandoned and that the study of the existence or absence of contracts should be substituted. Dorfman believes the key concept is that of externalities and that the presence or absence of property rights is not a fundamental way of viewing a problem. He focuses at-

tention on physical interdependence and discusses the effects of property rights on utilization of the resource. Ciriacy-Wantrup and Bishop examine the institutional performance of common property institutions and conclude there are many examples where these tools serve adequately for the management of public property. However, they warn about the dangers of neglecting the distinction between common property institutions and the absence of rights to property. They are not the same thing.

Attempts have been made to provide explanations of the emergence of property rights over time (Demsetz 1967). It is argued in an historical context that property rights reflect economic realities and that rule changes are a function of a balancing of the costs and benefits of such changes. Without attempting to assess the historical validity of these arguments, this article maintains that the contemporary situation is more complex. Specifically, public policies can influence the environment within which property rights are utilized and need to be considered simultaneously with rule changes.[1]

Economic Rent

Economic rent is one of the most durable of all economic concepts, and it is not surprising that it would emerge in a key role as a result of increased resource scarcity. When scarcities develop suddenly, there may be a reluctance to permit economic rents to increase significantly, perhaps because of a belief that the increment is largely unearned and that windfall profits should not accrue to those who happen to be in control of strategic resources. Yet, the temporary existence of rent, or quasi-rent, may serve as an incentive for the development of substitute supplies.

The concept of economic rent serves another purpose. The existence of quasi-rent may become a necessary condition for structural change in property rights. When a resource can command a return greater than that required to keep it in production, political incentive exists either to control the price so that the rent does not accrue—which has happened for some energy supplies—or to shift some part of the bundle of rights into the public sphere—which has happened for land. As noted above, if the rents are quasi, that is, if they are subject to disappearance with the development of substitutes, rents may serve a socially useful purpose. However, when the substitutes are not in sight, the citizen may have difficulty supporting a policy that will permit rents to accrue only in the hope substitutes will appear.

The existence of economic rents also often establishes multiple policy options that are equally efficient in a Pareto sense but which differ in their distributional implications. The utilization of conceptual devices such as basin-wide firms, which do not account for economic rent that arises because of locational or geographic differences, often suggests there is only one policy which is "Pareto" efficient (Kneese 1962). In fact, there may be several if the division of economic rent is introduced as a variable. The reader is referred to chapter VIII in Stoevener, et al., 1972, for a demonstration of this phenomenon in a case study situation.

The Division of Powers and Conflicts Among Jurisdictional Units

Property rights have meaning only within a system of law. Under our system of government, private rights to real property are typically defined in state law with local and state government sharing administration. Of course there is public ownership of real property at all levels of government.

When dramatic changes occur in the demand-supply relationships for natural resources, the accomplishment of national objectives may be influenced. National policies may then be formulated for the changed situation. The changed situation and the national policies may place stress on property rights that are defined and administered at other levels of government. When a conflict between national objectives and the administration of property rights at the local level occurs, the stage is set for actions that will redefine the division of powers.

The governmental aspects of the problem go to the heart of our political system. Modern technology may be such that a complete ac-

[1] I have benefitted from reading an unpublished manuscript by Daniel W. Bromley entitled *Property Rules, Liability Rules and Environmental Economics: Toward a New Paradigm*. Bromley draws upon Calabresi and Melamed who substitute the term "entitlement" for "property rights" and then discuss various types of entitlements. There are entitlements protected by property rules, entitlements protected by liability rules and inalienable entitlements. This classification provides greater precision and philosophical depth than does the more general term, property rights. But in the context of this paper, the greater refinement and precision does not change the analysis or the conclusions.

counting for interdependencies requires large jurisdictional units. Yet, the division of powers and the desirability of widespread participation in public decision-making may make necessary jurisdictional units that are more local in nature. Herein lies one of the major problems of our time.

Three Examples of Resource Use Conflicts

Land Use Regulation

A number of states have enacted land-use legislation, and national legislation has been proposed. The motivation for the legislation apparently is a dissatisfaction with the consequences of private holdings in land and a belief that the land approach holds a key to the solution of many resource and environmental problems. The proposed national legislation has been designed to enhance the capacity of the state and local governments to cope with the problems that cluster around land use. State land-use legislation usually either strengthens the capacity of local government to deal with such problems or permits state action if local government does not perform.

This emphasis on state and local government is consistent with a disenchantment with big, central government. Nevertheless, there appear to be conflicts implicit in such an approach unless that which occurs at the local level is related to the macro trends at the root of the problems.[2]

Our national policies reflect the requirements of an industrial society. The maintenance of a high level of employment and the development of metropolitan areas as a means of organizing economic activity are examples of such requirements. Low-cost, abundant energy and a transportation network centered around the automobile have been land using in effect, and land has not been viewed as a limiting factor in national policies. However, control of the use of land is one tool available at the local level which holds some prospect for managing growth and change (Dawson). The tool is a crude one and there are, typically, multiple objectives in its use (Ervin et al.).

Stoevener notes that local objectives include the minimization of externalities, the provision of public goods, and minimization of costs in the provision of certain public services. All of these objectives follow logically from a motivation to manage growth. Yet, the exercise of control at the local level may not result in desirable policies for at least two reasons. (*a*) An optimal policy for a particular jurisdiction may impose external costs elsewhere. For example, a marginal cost pricing policy for water, sewer, and other utilities in a city may impose external costs on surrounding areas unless they have comparable policies. (*b*) There will be macro consequences of land-use policies that significantly shift property rights between the private and the public sphere or which change the distribution of property rights within the private sector.

At the national level, fiscal, monetary, credit, and tax policies have encouraged widespread ownership of rights to real property. Home ownership has been a national objective, and institutions have been developed that have made this possible on the basis of potential rather than realized wealth. However, housing may well emerge before the end of this decade as a high-priority domestic concern. Home ownership may become increasingly difficult for those of low and medium income because the cost of housing may increase more rapidly than income. There appear to be at least three reasons for the increased cost of housing. (*a*) Building and environmental codes add to the cost of housing, and these are cumulative over time. (*b*) Certain housing cost factors tend to rise more rapidly than the general price level. (*c*) Since 1965 the increased reliance on monetary policy to control inflation has had a particularly severe impact on housing.

The above provides some insight into the reasons the market for real property is not well understood. If the traditional attributes of land and real property are focused upon, some of the more important considerations in decision making and policy will be missed. The purchase of real property often provides an opportunity to buy debt; in an inflationary economy, debt is a desirable asset.

Lee and Rask estimate that a Corn Belt farmer operating under specified assumptions will increase his bid price for land $115 per acre for every 1% increase in inflation. Inflation rates were permitted to vary from 0 to .12 per annum in their model. Dovering has noted, "if about half of the purchase price is credit-financed, the rate of inflationary capital gain

[2] The focus here is on problems of growth. Of course many communities lose population and economic activity as a result of change but the problems addressed in this paper arise mainly in a growth context.

on the equity would be twice that of inflation" (p. 35). The demand for debt during inflation and the opportunity provided for low- and middle-income people to accumulate an estate are examples of market attributes that warrant additional investigation.

Figure 1 illustrates the relative importance of real estate investment by income levels. If holdings of real property among low- and middle-income groups decline, there may be profound political implications. The widespread distribution of rights in real property probably results in a more conservative attitude toward property in general. If land-use policies are regressive in their economic effect, their adoption may fly in the face of distributive objectives.

Energy Resource Development and Western Water Rights

The energy use of an industrialized world has focused attention on the energy resources of the United States. Despite the physical validity of entropy, in the time frame of realistic planning, it is the environmental and distributional consequences of energy development that take center stage. Land that includes undeveloped energy resources has become increasingly valuable. The existence of unrealized economic rent directs attention to the possible beneficiaries of this potential. The political economy is obviously very different if the lands are in private ownership than if they are publicly owned.

In the case of coal development in the West, the environmental hazard and life-style impact tend to be location specific and in relatively less populated areas. Yet the reserves are so enormous that the benefits will be widely dispersed because the development of these reserves would add significantly to the nation's energy supply. The benefits are to the many; the costs would be borne by a small group.

Water is needed for energy resource devel-

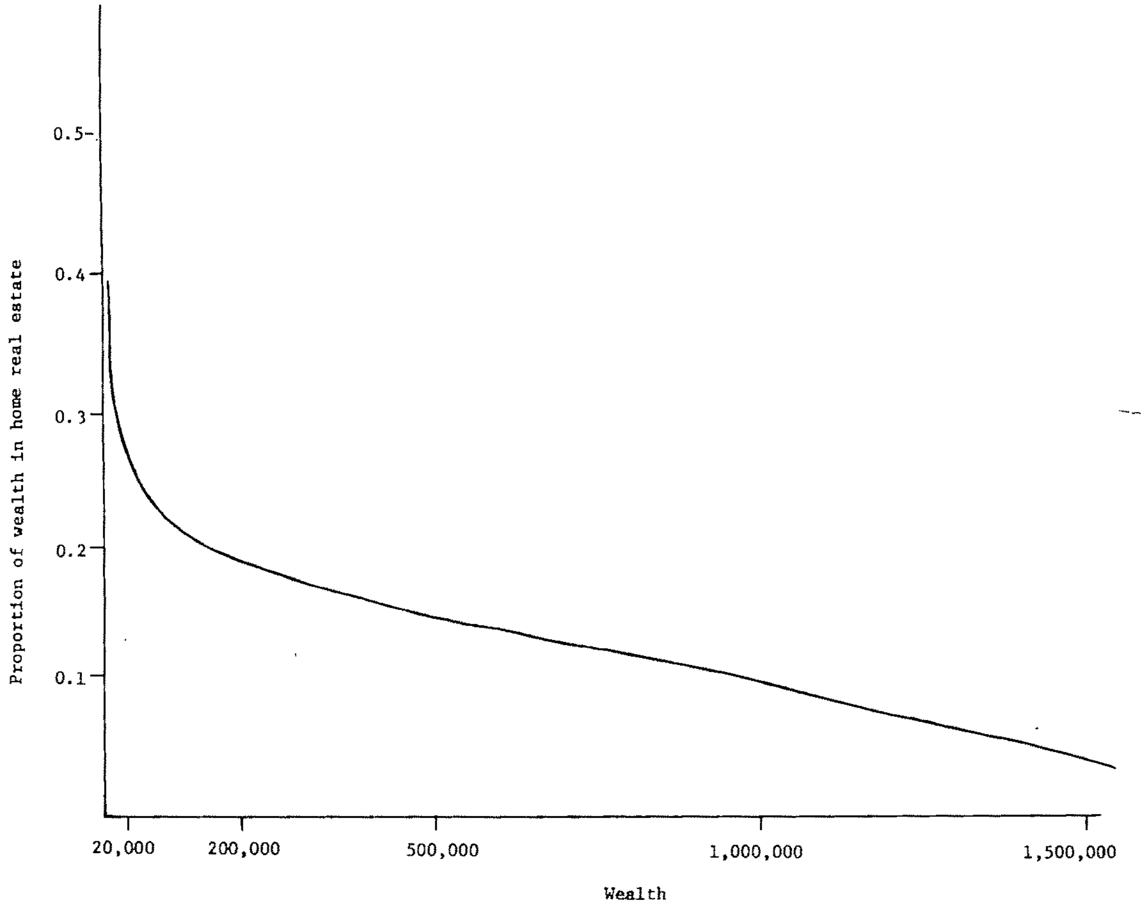

Figure 1. Wealth and real estate investment, United States
Source: Erlandson, Mark J., Herbert H. Stoevener, and Rosalyn Shirack (1977). Based on 1962 data.

opment; but in most western states all available water has been appropriated, with private rights in water being defined in state law. Thus, the federal government is placing pressure on the states to improve the efficiency of water use so that water will be available for energy development. The quantity required is not so great as to create high opportunity costs in its lowest valued use, agriculture. The federal government may rely upon the reservation doctrine for waters which arise on federal lands; however, such waters are often not properly located for energy development.

Because there is pressure on the executive branch to develop a comprehensive energy policy, it is likely to be the executive branch which will encourage development. However, the final disposition of the matter may well rest with Congress, and it is not clear that Congress and the executive branch will agree. In fact, in Montana and the Dakotas, the Congress has referred to the states the allocation of water on reclamation projects that might be used for energy development. The reasoning apparently was that water allocation was not properly a matter for the federal government to decide.

The need for water for energy development is occurring at a time when the demand for water is increasing for both public and private uses. This increasing competition for water provides inducement for greater economic efficiency in the use of water. However, water and mineral rights provide a means for the states to avoid some of the costs and share in some of the benefits of energy development.

Several states are attempting to share in the economic rent from energy development through the imposition of severance taxes. It is not yet clear what the ultimate use of these revenues will be, but preliminary indications are that they will be used as a substitute for other state revenues. This raises again the question of the appropriate jurisdictional unit for matters of this kind. The states cannot reflect the full national interest; on the other hand, they may not reflect well the interests of those at the local level who are damaged most.

The ultimate consequence may be to strengthen the federal government relative to the states. This would fly in the face of other trends that suggest it is the public preference to decentralize decision making in resource matters in favor of state and local government.

Property Rights and Marine Resource Development

The ocean fishery has long been used as an example of the undesirable consequences of common property resources (see Gordon and Scott), but changes are in the wind with respect to the management of ocean resources (Christy).

The extension of the two hundred mile limit and the creation of regional councils for fishery management are significant developments. They are an assertion of specific rights in the ocean. It still remains for states and nations to develop procedures for the management of these common property resources. History may show that recent developments were a first step in creating the necessary jurisdictions for management of the common property resource.

Improved technology for fish culture and breeding have increased the potential value of property rights in the ocean fishery. Oregon and Alaska have passed legislation creating private rights to salmon returning to hatcheries, and additional legislation is anticipated in Washington. Research and development costs are spread among the population of the state, with the benefit accruing to particular groups. Both the legislative and the executive branches have an interest in such policies, because there is political pay-off, and because there is a need for a continuing role of the executive branch in the administration of these laws.

Summary of the Examples

The three examples represent very different situations with respect to natural resource policy, yet they have something in common with respect to institutional response. The utilization of private rights in land, within the context of the legal and political system and as shaped by public policies and programs, has made physical interdependencies affecting the utilization of space and the atmosphere a matter of social concern and has led to attempts to manage growth at the local level by land-use measures. In the case of coal development, private rights in water and minerals become of crucial importance and this leads to the issue of federal-state relations. The power of the states to levy taxes makes possible a redistribution of the rents arising from the utiliza-

tion of coal deposits. For the oceans, the increased value of the products yielded by the oceans in addition to technical change may well cause a redefinition of rights.

The examples demonstrate that increased scarcity, with the resulting increase in economic rent, is not sufficient for a redefinition of property rights. Certain political conditions must also be present if change is to occur. Further, the kind of change which is probable will depend very much on the distribution of income and costs. But the distribution of income and costs relevant in a political context may differ from distribution by income levels, occupation, or tenure, the usual ways of measuring distribution in economics.

Summary and Conclusions

Summary conclusions are presented below. These conclusions are stated in a policy context, and there are research and educational implications which are not made explicit.

Macro policies are frequently adopted in response to changing conditions of resource availability to cope with an employment objective, changes in the general price level, or income distribution. The pursuit of these short-run objectives often results in policies that are in direct conflict with the most appropriate policies to bring forth additional supplies and conserve use. Under such circumstances, investigations of ultimate resource availability and long-run supply response does not constitute an adequate response to policy needs.

Pressure on the existing system of property rights may result from the exercise of market power, political power, public policies, or the operation of demand and supply conditions for a particular natural resource. Prior to changing the rules that specify the rights to property, it is well to diagnose the cause of the dissatisfaction with the present rule system. For example, pressure on property rights in land stems from a need to deal with the consequences of growth. While the tools are fashioned to be exercised at the local level, growth itself stems from national policies designed to maintain employment, the industrial state, and existing life-styles.

Policies that will affect the distribution of rights to property can either be progressive or regressive in effect. Many past policies have been generally progressive. Proposed rule changes may not but should be investigated from this point of view.

Structural changes in property rights under our system of government inevitably raise the question of appropriate jurisdictions. Local, state, and federal government are all involved. The control of the states over the definition of water and mineral rights may impose constraints on the development of energy resources needed to serve national needs. But whether the states are the most appropriate units to balance social costs and benefits is indeed an open question.

Herein may lie one of the more fundamental emerging conflicts in our society. National policies undoubtedly will be designed to promote, or at least maintain, the requirements of the industrial state; but the full costs of these policies will not be reflected at the national level, and the tasks of managing growth will fall to state and local government. Yet, neither can these units fully reflect social costs and benefits.

The current challenge to private rights in property comes from two directions. One is that the exercise of private rights in property creates significant externalities because of physical interdependencies in the natural environment. The other is that unearned increments may accrue to those holding rights, and that the existence of these increments has little to do with bringing forth additional supplies.

One of the apparent assumptions underlying land-use planning and control is that land is becoming increasingly scarce. Trends in land prices would support such a view; but, as noted, at least part of the demand is stimulated by inflation and by credit and tax policies. Further, it may be that social utility is being reduced more by the increased scarcity of certain common property resources, such as open space and atmospheric quality, than by increased scarcity of the traditional attributes of land. If this is the case, the development of policies for the management of resources held in common is appropriate. Land-use control, as currently practiced, is an exceedingly crude tool for this purpose.

A significant strength of property rights is that they provide for separability. Quality, whether it is environmental, life-style, or commodity oriented, becomes an issue only if there is non-separability and heterogeneity (Castle 1972). The "bundle of sticks" concept

implies separability, and separability makes possible the transfer of part of the bundle among private owners. Although the extent is unknown, this transfer is occurring. Attempts are being made to socialize "development" rights, and private rights have been and are being created for minerals, hunting, recreation, and other uses. Changing conditions of availability undoubtedly will result in even greater fragmentation. Of course, if fragmentation does not reflect physical interdependencies adequately, problems may be created.

The unearned increment issue cannot be settled in this paper. To the extent technology and capital can be substituted for natural resources, quasi-economic rent serves a social purpose by the incentive it provides for the development of substitutes. It is here that economic research may be able to bring supply response considerations into focus with macro objectives pertaining to income distribution, employment, and inflation.

In summary, the market for rights and property are influenced greatly by public policies that have multiple objectives, as well as by demand and supply for the resource itself. Rule changes may be counter productive or ineffective if the underlying cause of the pressure on property rights is not modified, removed, or at least understood.

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Endangered Species and Uncertainty: The Economics of a Safe Minimum Standard

Richard C. Bishop

Species extinction irreversibly narrows the reservoir of potential resources. The future repercussions of this narrowing are uncertain. This paper develops the safe minimum standard (SMS) approach to public decisions involving endangered species. The SMS approach is based on game theory and calls for avoidance of extinction unless the social costs are unacceptably large. The level at which costs become excessive is a matter of intergenerational distribution. The paper also explores important linkages between the SMS approach and recent literature on preservation of natural environments.

Key words: endangered species, game theory, resources, social costs.

Suppose that a hydroelectric dam has been proposed which would flood the last remaining habitat of an endangered species. Suppose further that there is no alternative method of preventing extinction of this species except to maintain its habitat in an unflooded condition. The goal of this paper is to explore the conceptual issues which are central to the development of an economic framework for confronting public decisions of this type, decisions which are increasingly in the public mind since recent court cases involving the snail darter in Tennessee and the lousewort in Maine.

To achieve this goal, the paper will draw heavily upon the work of S. V. Ciriacy-Wantrup. Wantrup (1968) included plant and animal species in his class of flow resources with a critical zone. Such resources are renewable within limits but have a threshold or critical zone such that once the critical zone is reached, further depletion is irreversible. Wantrup placed major emphasis on the problem of uncertainty associated with irreversible depletion of critical zone flow resources. Following this line of reasoning, the first task in the paper will be to see how extinction irreversibly narrows the reservoir of potential resources, creating the possibility of large, though uncertain, future social losses.

One policy alternative to cope with this problem would be to maintain sufficient population and habitat to assure survival. This is Wantrup's (1968) safe minimum standard of conservation (SMS). But Wantrup did more than name a policy alternative. He proposed an approach to public decisions about whether or not the SMS would be established. This "SMS approach," as it will be termed here, will be reexamined in the second section of the paper. While the SMS approach has theoretical roots in game theory, several problems with strict adherence to the minimax strategy necessitate use of a modified minimax principle as the basic decision rule of the SMS approach. This decision rule states that the SMS should be adopted unless the social costs of doing so are unacceptably large. How much is "unacceptably large" must necessarily involve more than economic analysis, because endangered species involve issues of intergenerational equity.

Up to this point, we will have ignored important new literature on the conflict between preservation of natural environments and development of the resources in such environments. This work has largely evolved from the Natural Environments Program at Resources for the Future under the leadership of John V. Krutilla. While the RFF work has not dealt in any great detail with endangered life-forms, heavy emphasis has been placed on the prob-

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lem of irreversibility and uncertainty. Furthermore, some of Krutilla's concepts extend back to Wantrup's work. Ten years ago, Krutilla wrote, "It must be acknowledged that with sufficient patience and perception nearly all of the argument for preserving unique phenomena of nature can be found in the classic on conservation economics by Ciriacy-Wantrup" (p. 778, f. 3). Thus, it is important to ask what Krutilla and his colleagues have learned that may prove helpful in dealing with endangered species. In fact, the RFF work supports the basic decision rule of the SMS approach and has added to our understanding of the social costs associated with choosing the SMS strategy.

The paper will conclude with some additional observations relating to the SMS approach. One possible objection to the SMS approach is that even if many species are lost, millions of others will remain. However, since each species has unique qualities, its loss would create uncertainty despite the continued existence of a multitude of others. The cumulative costs of efforts to conserve large numbers of endangered species and potential applications of the SMS approach to other policy issues will also be explored.

Before turning to the problem of irreversibility and uncertainty, it is necessary to define "endangered species." A species or subspecies of plant or animal is endangered if it is sufficiently close to extinction to make its survival questionable beyond the next few years or decades. Endangered life-form will also be used as a synonym. No attempt will be made to distinguish between endangered species (and subspecies) on the one hand and "threatened" or "rare" species on the other.

The Problem of Irreversibility and Uncertainty

In the hypothetical problem of the water project that would render a species in the flooded area extinct, several rather straightforward aspects of the decision problem can be identified. First, if a correct benefit-cost analysis is done and the B-C ratio exceeds unity, saving the species would involve social costs in the form of net benefits forgone. There may, of course, be additional, out-of-pocket costs to maintain the species. Examples are outlays for research to better understand its needs and expenditures for law enforcement to prevent shooting or inadvertent harassment by curious visitors. Second, maintaining the species may itself generate benefits to at least partially offset the costs of conservation efforts. For example, the species, once it has recovered, may be valuable for viewing or may even support a sustainable harvest for hunting, furs, or some other product. Also, there may be joint benefits from conservation. Assume, for example, that the habitat can be used for wilderness recreation without harm to the endangered species—provided it is not flooded. Third, we might explore the public good aspects of species existence and the reasons a private electric company, when choosing a project site, might not consider society's interest in the endangered species. Not only are these aspects of the problem straightforward to the economist, but they are covered elsewhere (Bachmura; Ciriacy-Wantrup and Phillips; Phillips; Amacher, Tollison, and Willet; Bishop; Bishop and Stevenson). What is not so straightforward, however, is the problem of irreversibility and uncertainty which the SMS approach addresses. The nature of this problem follows from the economic concept of what constitutes natural resources.

"Resources," someone has observed, "are not, they become." Stated less concisely, characteristics of the natural environment "become" natural resources through changes in human tastes and preferences, income levels, population levels, technologies, social institutions, and public policies. The earth's flora and fauna are part of a vast reservoir of potential resources, only a relatively small proportion of which are recognized as actual resources at any one time.

The effect of extinction is to reduce irreversibly this reservoir. While there is much interest these days in genetic engineering, the barriers to replacing lost life-forms are immense. Even if genetic engineering does gain the capacity to create complex life-forms at will, extinct species may be out of reach for lack of "blueprints."

Furthermore, the long-run implications of permitting the reservoir to be reduced are shrouded in both "social" and "natural" uncertainty. By social uncertainty is meant the lack of knowledge about future time paths for the income levels, technologies, and the other variables that will determine which life-forms eventually become resources and which will not. History is replete with examples where

unanticipated events caused natural phenomena to become resources. Our future must certainly be equally unpredictable.

Natural uncertainty refers to the large gaps in knowledge about the characteristics of flora and fauna that may eventually prove useful to humans. Though less well-known to economists, natural uncertainty is as impressive as social uncertainty. It is an understatement to say that there is still a great deal to be learned about nature.

Return now to the hypothetical hydroelectric project. Beyond the benefits and cost of constructing the dam vis-a-vis maintaining the valley for endangered species propagation and wilderness recreation, we have the problem of not knowing the "ultimate" implications of extinction. Perhaps the species in question will never turn out to be a more economically valuable resource than it is today. Perhaps it holds the key to a cure for cancer, or an unforeseen food source, or the makings of some other new resource; perhaps it may be worthless. No one can say for certain.

In sum, potential extinction creates an important public policy issue because there is little basis to judge which life-forms can be discarded without serious future social and economic consequences. To choose extinction creates the possibility of large future losses.

This, it is important to add, has been a neglected aspect in the present growth/no-growth debate. On the one hand are alarmingly high rates of exhaustion of several nonrenewable resources, population growth with accompanying pressures on food resources, and cumulative destruction of natural resources which many consider to be important for the quality of life if not essential for the maintenance of human life itself. On the other hand, many economists see sociotechnical progress as man's primary defense against doomsday. But can progress keep pace?

The earth's life-forms are important to this problem in at least two ways. First, as a reservoir of future resources, the earth's life-forms are among humankind's best hopes for continued technological progress through research in the natural and biological sciences. Second, increased dependence on technological change means that the importance of the biosphere for environmental monitoring also increases (Jenkins and Bedford). The brown pelican, osprey, and bald eagle played this role in warning that DDT was concentrating in living organisms. Yet, as dependence on the living reservoir of potential resources appears to be growing, the size of that reservoir is on the verge of shrinking substantially through extinction.

A solution to this problem of irreversibility and uncertainty would be to adopt the SMS. However, as noted earlier, to adopt the SMS may itself entail social costs. How should society go about deciding whether or not to adopt the SMS? As Wantrup pondered this question, he recognized the theoretical basis for an approach in the emerging literature on game theory, particularly as it related to the problem of decision-making under uncertainty.

Game Theory and the SMS Approach

The game that is of interest here is the "two-person game against nature," with the opponents being "society" and "nature." Uncertainty is portrayed by assuming that nature chooses its strategy by some unknown mechanism. This picture of ignorance appears well suited to uncertainty about the prospects of large losses through extinction of species. One solution suggested by the theory of games against nature is to employ the minimax principle—society should choose the strategy that minimizes maximum possible losses (Luce and Raiffa).

The game is depicted in table 1. In our example, society has two strategies: (1) E (for extinction), which involves building the dam; and (2) SMS, which involves leaving the valley unflooded so that the safe minimum standard is maintained. To make the abstract game as simple as possible, only two possible social states are assumed. In state 1, nothing unanticipated occurs in the future to create large social losses if the species ceases to exist. In state 2, the species unexpectedly turns out to

Table 1. Matrix of Losses

Strategies	States 1	2	Maximum Losses*
E	0	y	y
SMS	x	x-y	x

* Assumes $x, y > 0$.

be worth a large amount as, say, a cure for cancer or a new energy source. Let this amount be symbolized by y. Let x, on the other hand, equal the present value of net benefits from hydroelectric power generation. We assume x is known with certainty and that it includes an allowance for the costs of losing wilderness recreation and the species as an object to be viewed (since these values are known before the project is built). However, the possible value of the species as a cancer cure or energy source (y) is not included in x.

Payoffs in a game matrix must proceed from some base point. For ease of exposition, it is most convenient to make this the intersection of E and state 1, so that this payoff takes on the value of zero. On the other hand, if E were chosen and state 2 occurs, the social loss would be y. If SMS is chosen and state 1 obtains, the loss is x, since society would have lost the net benefits of generating electricity at the site. Under this strategy, an outcome of state 2 means that the loss (possibly negative, indicating a gain) is $x - y$. The third column of the matrix shows the maximum possible loss under each strategy. The minimax principle indicates that the strategy should be chosen which minimizes maximum possible losses. Thus, E should be chosen if $x > y$, SMS should be chosen if $y > x$, and equality of x and y would indicate indifference.

The Modified Minimax Principle

Three problems with this approach immediately come to mind. First, Luce and Raiffa consider the minimax solution to be conservative in the extreme. In the present case, for example, the safe minimum standard would be adopted if its costs (x) are only slightly less than the social losses (y) that would be incurred under the worst conceivable future situation. Obviously, to live is to take chances. If the costs of avoiding uncertainty become unacceptably large, we accept the chance of large losses rather than blindly pursuing a minimax approach, and policies concerning endangered species should reflect this.

The second problem relates to the assumption in game theory that while the probabilities of alternative outcomes are not known, the outcomes themselves and their values under alternative strategies can be foreseen. That is to say, the payoff matrix is assumed to be known with certainty. While this is a useful construct for differentiating theoretically between risk and uncertainty, it is not very realistic. If the problem of irreversibility and uncertainty is adequately characterized in this paper, then not only are the probabilities of alternative outcomes poorly understood but also the outcomes themselves and the associated losses. In the context of table 1, y is not known beyond the general observation that it could be "large." If y is not known, it is unclear whether E or SMS is in fact the minimax strategy.

Third, a payoff matrix such as table 1 is static and ignores who will receive the gains and bear the losses of following the alternative strategies. The problem at hand clearly involves long periods of time and affects decidedly different gainers and losers depending on the decision. In the water project example, choosing the SMS involves a sacrifice on the part of near-term members of society who will either have to pay more for electricity generated by alternative means or do without the electricity altogether. The beneficiaries of the SMS choice will be members of future generations who will avoid the losses if state 2 obtains. On the other hand, electricity consumers will gain if E is chosen but at the expense of imposing uncertain but potentially large losses on future generations. How is this problem of intergenerational equity to be dealt with in choosing a strategy? This question is clearly beyond the scope of the minimax principle.

These three problems are of sufficient concern to raise serious questions about the wisdom of strict adherence to the minimax principle in public decision-making. However, this much is clear: the lower the costs of the safe minimum standard (x), the less compelling these objections become. The lower the costs, the less "overly conservative" is the SMS strategy. Furthermore, the lower the costs, the more likely is $y > x$ to hold so that the SMS strategy is actually the minimax solution. Finally, the lower the costs, the smaller is the burden on the present generation of avoiding the imposition of uncertainty on future generations. This argument leads to a modified minimax principle which expresses the basic decision rule of the SMS approach: adopt the safe minimum standard unless the social costs are unacceptably large.

This decision rule immediately raises questions about how high costs would have to be before they become excessive. Clearly, however, this is a question of distribution with which economics is ill-equipped to deal. The

point at which costs become unacceptably large is dependent on the willingness of the present generation to bear costs so that the position of future generations will be less uncertain. Like all choices related to distribution, these choices must ultimately rest with society and the institutions it has created to deal with such issues. In the safe minimum standard approach, the role of the economist is to help public decisionmakers become aware of the nature of the economic issues that arise when life-forms are endangered, to evaluate the social costs of choosing the safe minimum standard, and to help the decision-maker view these costs in perspective.

It should be noted in passing that Wantrup's (1968, pp. 251–68) development may have been more normative than the exposition presented here. While the present statement is clearly normative in the sense that it suggests how the decision-maker ought to choose between E and SMS, many of Wantrup's remarks can be interpreted as going the extra step of arguing that the SMS strategy should be chosen.

Except for this caveat, the SMS approach has just been described more or less as Wantrup originally developed it. More recently, several economists at RFF have also struggled with this problem of how to cope with irreversibility and uncertainty in the context of public decision-making. It is important to ask whether additional concepts and principles have evolved from this research that may be useful in dealing with endangered species.

Recent Developments from the RFF Research on Natural Environments

Let us again consider the hypothetical water project. How would the RFF group deal with this problem? Following the excellent summary by Krutilla and Fisher of the RFF work, we must differentiate between the "development benefits" and the "preservation benefits" associated with this proposal. Development benefits, which will be symbolized by B_d, consist of the gross social benefits of development minus the direct costs of building the dam, buying the land, etc. In particular, there is no allowance for the environmental cost of wilderness recreation and wildlife viewing that would be lost because of the project. In the Krutilla-Fisher framework, these are counted as part of preservation benefits, symbolized by B_p, where B_p represents the present-valued social benefits associated with maintaining the area as a wilderness and habitat for endangered species, minus the costs of wilderness recreation, such as the costs of constructing and maintaining trails. To avoid double counting, however, B_p does not include any allowance for the cost of electricity generating resources that must necessarily remain unutilized if B_p is to be realized.

Krutilla and Fisher foresee a number of problems with conventional approaches to estimating B_d and B_p, four of which will be discussed here.

Option Values

Option value has had a controversial history since its introduction by Weisbrod. The main issue from the standpoint of benefit-cost analysis was whether option value represents a new benefit or whether it is simply the traditional concept of benefits viewed from a different direction. For a time, it appeared that Cicchetti and Freeman had settled the issue when they defined option value to be a risk premium as that term was originally defined by Friedman and Savage. This definition seems to have been accepted by most economists as one form of option value, although recent writers have demonstrated that option value may be either positive, negative, or zero, even for a risk-averse consumer (see Henry). Furthermore, a new concept, which Krutilla and Fisher choose to call "quasi-option value," has emerged. This second kind of option value is not a risk premium, but rather the extra value of choosing not to take irreversible steps if new information about the outcomes of alternative decisions will become available in the future (Arrow and Fisher; Henry; Krutilla and Fisher, pp. 69–72). For the rational consumer or producers, quasi-option value would be positive, regardless of risk preferences. Both concepts would appear to be applicable to the present case, yet no methods are now available to estimate these values. Thus, it will be necessary to deal with an approximation of true preservation benefits (defined above as B_p). Let us symbolize "*measurable* preservation benefits" by B'_p. Further, assuming that option value is positive, it is clear that $B'_p < B_p$, since both option values cannot be estimated by known techniques. Lest an impor-

tant point go unnoticed, recognition of these two option values is the principal strategy of the RFF group for coping with the irreversibility and uncertainty associated with destruction of natural environments.

Existence Value

Another unmeasurable benefit of the preservation alternative is existence value. Existence value is not a reflection of risk preferences as is option value, nor does it result from the prospect of new information as does quasi-option value. Rather, existence value reflects the utility that people receive from simply knowing that something exists. For example, many people would be willing to pay something to know that the blue whale will continue to exist. This willingness to pay is not attributable to any expectation of benefiting directly through eventual consumption of whale products or aesthetic enjoyment of whales, but rather to knowledge of the whale's existence (Barkley and Seckler). Because species existence is clearly a public good, there is no market in which to express this willingness to pay. Some writers, including Krutilla, prefer to treat existence value as yet another form of option value. In any case, here is an additional reason to argue that $B'_p < B_p$.

Ambiguity in Property Rights

Traditional benefit estimation is based on willingness to pay. This may raise questions about the appropriate measure of consumer surplus. In the present case, if property rights in the endangered species were attributed to those who may eventually benefit from its continued survival, then the correct measure of preservation benefits would be the amount that would be required to compensate them completely for the loss. "Willingness to receive compensation" as a measure of consumer's surplus would generally be greater than the amount preservation beneficiaries would be willing to pay to see a species survive. Mishan has argued that willingness to receive ought to be the measure of benefits where natural amenities are at stake. To the extent that his argument is accepted, conventional measures of B'_p would underestimate true benefits, and this would be another reason to suspect that $B'_p < B_p$, where measurable benefits are based on willingness to pay.

Technological Change

Another problem with conventional benefit-cost analysis relates to the asymmetric incidence of technological change. The asymmetric incidence concept, which can be traced back to Wantrup (1968, pp. 46–47), has received a great deal of emphasis in the work at RFF (Krutilla, Smith). Minerals and other products of extractive industries that contribute to development benefits are generally used as raw materials in the production of consumer durables and energy. Here, technology hopefully will continue to provide substitutes in production which do not significantly affect the satisfaction of consumers. Other things being equal, for example, one does not notice whether electricity is produced from fossil fuels, solar generating facilities, or nuclear fission. On the other hand, many of the products of natural environments, particularly enjoyment of natural amenities, enter directly into consumption. Hence, there are few, if any, opportunities for development of new technologies which can substitute inputs without affecting the qualities of natural amenities that yield satisfaction to consumers. With economic growth and technological progress, the value of natural amenities should increase relative to the value of more conventional commodities. An initial attempt to incorporate this phenomenon into benefit-cost analysis is found in the widely cited study of Hell's Canyon; Krutilla and Fisher (pp. 84–150) summarize the study and cite earlier literature. To the extent that conventional benefit-cost techniques do not include this asymmetry, they will tend to overestimate B_d and underestimate B_p. If this argument is accepted, it would appear to be applicable to some threatened species like the California condor, southern bald eagle, and whooping crane, all of which attract attention for their aesthetic qualities.

For all these reasons (and others as well), the RFF group concluded that public choices between development and preservation must be approached in three steps. First, B_d should be carefully examined. If B_d is negative, clearly the development alternative is not economically justified regardless of environmental impacts. The research summarized by Krutilla and Fisher discusses several cases where development of natural environments did not survive close scrutiny even before environmental damages were introduced.

Of course, there are bound to be cases where B_d is positive. The second step, then, is to evaluate B'_p and compare this with B_d. Measurable preservation benefits alone may be sufficiently large to offset B_d, even though $B_d > 0$. This was the result, for example, in the Hell's Canyon study.

However, it is too much to hope that the world will always be so simple, and there are likely many cases where $B'_p < B_d$. Here, however, caution is advocated. Because of the two option values, ambiguity in property rights, and for other reasons, it is entirely possible that true preservation benefits (B_p) are still larger than B_d. Hence, Krutilla and his colleagues advocate giving the "benefit of the doubt" to preservation. Presumably, this means that the preservation alternative should be chosen unless development, after considering B'_p, is still economically attractive.

At this point, some conclusions about the relationships between the safe minimum standard approach and the work at Resources for the Future can be drawn. First, the basic decision criterion is the same for both approaches. Note that B_d–B'_p can be interpreted as the measurable social costs of the preservation alternative. Thus, in dealing with an endangered species, B_d–B'_p is an estimate of the costs of the safe minimum standard. Giving the "benefit of the doubt" to preservation is more or less equivalent to a decision rule stating that preservation should be chosen unless the measurable social costs are unacceptably large. Thus, while the RFF group has developed somewhat different terminology (e.g., preservation alternative rather than safe minimum standard) and includes no explicit treatment of the problem of irreversibility and uncertainty in a game theory framework, the basic decision rule remains the same as under the SMS approach.

Second, the RFF work is important to the present paper because of the light that it casts on the social costs of adopting the safe minimum standard for endangered species. Beyond the out-of-pocket research and management costs, there are likely to be the opportunity costs of habitat maintenance. The major threats to habitat are the types of "development alternatives" that have been a focal point for the RFF work. Conceptually, if the x of table 1 is taken to be the true, though unmeasurable, social costs of the safe minimum standard, then $x = B_d$–B_p. To the extent that decision-makers must work instead with measurable social costs, the results of the work at RFF indicate that they are working with overestimates of the true social cost and should consider the possibility that option value, existence value, and the other concepts may be sufficient to tip the scales in favor of the SMS alternative.

Finally, a word of caution needs to be expressed. There is some tendency in the literature to conclude that the problem of irreversibility and uncertainty is solved by including option values in the definition of B_p. This may be suitable for the general problem of evaluating preservation of natural environments. There is an element of irreversibility and uncertainty in cases where development would destroy natural environments, but it seems reasonable to argue that the problem is much larger for endangered species. To the extent that natural environments do not contain endangered species, it is hard to imagine their significance extending beyond aesthetic enjoyment and perhaps unusual research materials. Living resources, on the other hand, have proven valuable in production of food, building materials, medical products, energy, and many other commodities, as well as aesthetic enjoyment and research materials. The tremendous natural and social uncertainties associated with living potential resources means that option values are also unknowable beyond the next decade or two. To the extent that irreversibility may affect members of society over this time horizon, the option values help to understand the qualitative nature of B_p and may eventually even yield to quantitative evaluation. But, in no way do they solve the longer-run problem of irreversibility and uncertainty.

Now that the concepts embodied in the SMS approach have been explored and reviewed in relation to the RFF work, the paper concludes with some additional observations about the approach.

Concluding Observations

One question not addressed as yet relates to the great number of species which are not endangered. It has been estimated that there may be 10 million species and subspecies of plants and animals on earth (Raven, Berlin, and Breedlove). If so, 8.5 million remain to be

discovered. With so many species present and apparently unendangered, could one argue that the SMS approach exaggerates the importance of individual life-forms? Unfortunately, the fact that millions of species will remain if one becomes extinct does little to reduce the problem of irreversibility and uncertainty. Living things are incredibly diverse and complex. Even two closely related subspecies may be so different that one will become a new agricultural or pharmacological resource and the other remains of little value. The loss of any species irreversibly reduces the reservoir of future resources quite regardless of the continued existence of millions of other life-forms.

Furthermore, the pace of extinction is increasing. A recent study by the Smithsonian Institution indicates that 10% of the plants in the United States are in jeopardy (Jenkins and Ayensu). Similar and perhaps more serious problems are emerging in the LDCs as development pressures on previously wild areas continue to gain momentum (Myers). If unchecked, these trends will eventually mean a narrowing of the reservoir of potential resources unparalleled in human history.

But this raises still another question about the SMS approach. While the costs of a safe minimum standard may be within tolerable limits when individual species are considered, is there a danger that, when an ever-increasing number of species must be protected, the cumulative costs will become intolerable? More research on the costs of conserving individual species should be helpful here. Based on recent studies, two preliminary observations appear warranted.

First, Bishop and Stevenson have argued that the costs of efforts to maintain most species are probably modest. This conclusion rests on case studies involving the California condor and an endangered leopard lizard. Efforts to establish a safe minimum standard for the condor involves controls on development of oil and other minerals, water resources, and land for suburban and agricultural expansion. The leopard lizard, in contrast, requires small adjustments in the use of off-road recreational vehicles at social costs which are not large. They conclude that most endangered species are more like the leopard lizard than the condor in the sense that their ranges are restricted and only minimal economic adjustments are required to achieve the SMS. If further research continues to support this assertion, it will mean that cumulative costs over large numbers of species will not be a major problem. Rather, the major public decisions will involve a minority of species (like the condor) that happen to be found at unusually costly locations.

Second, to the extent that cumulative costs do nevertheless rise, it is important to recognize that there will be offsetting benefits in some cases. For example, Ciriacy-Wantrup and Phillips found that the costs of maintaining the California tule elk were more than offset by the benefits of controlled public hunting (see also Phillips). In the terms developed in the preceding section, $B'_p > B_d$ for these animals.

It should be emphasized that the condor, leopard lizard, and tule elk are all U.S. species. The SMS approach has yet to be applied in the tropical countries with their low incomes and diverse, complex ecosystems. Myers reports that as much as 20% of the land in such areas as the Amazon Basin may have to remain in natural preserves if extinction on a massive scale is to be avoided. Here, cumulative costs may be a serious problem. More research would be especially helpful.

Finally, it is worthwhile to note that problems of irreversibility and uncertainty are not limited to endangered species, that the SMS approach may be applicable to a wider range of resource issues. This point is illustrated by two studies. Ciriacy-Wantrup (1964) has explored the SMS approach to the problem of urbanization on prime agricultural lands in California. The SMS strategy was defined in terms of diverting development to non-prime land. The costs of doing so would consist of the extra costs of development on less level, non-prime land plus possible additional transportation costs. However, the more pleasing views and resulting maintenance of attractive and productive agricultural areas in the valleys would generate benefits to partially counterbalance these costs. Kneese has argued persuasively that conventional benefit-cost analysis is not an appropriate approach to public decisions involving coal versus nuclear energy development because of the possibility that large amounts of radiation may be irreversibly introduced into the environment. He suggests that the additional costs of coal-fired electricity generation are not sufficiently large to justify this risk. While it is not identified as such,

this is clearly the same type of approach to public decision-making that this paper has chosen to call the safe minimum standard approach.

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Systems of Land Tenure, Allocative Efficiency, and Economic Development

P. C. Ip and C. W. Stahl

This paper discusses comparative efficiency of resource allocation under alternative forms of land tenure—sharecropping, fixed rental, wage cultivation, and owner cultivation. It shows that when transaction costs, the role of entrepreneurship, and economic incentives are explicitly introduced and analyzed within the framework of intersectoral interactions and linkages, land reform measures redistributing land to the peasants, substituting owner-cultivators for share tenants, tend to improve agricultural production efficiency, resource allocation between farm and other sectors, and contribute to economic development of less developed countries, contrary to conclusions reached by writers of the "equal efficiency" school.

Key words: economic development, land reform, production efficiency, transaction costs.

Introduction

The comparative efficiency of resource allocation in agriculture under alternative forms of land tenure is undoubtedly one of the most widely discussed and controversial issues in the economic literature related to land reform and agricultural development in less developed countries (LDC's). A large body of economists and other social scientists concerned with underdevelopment contend that tenancy (especially sharecropping) results in an inefficient allocation of resources as well as a reduced incentive to improve agricultural land. This school of thought also holds the opinion that to a substantial degree tenancies as forms of contractual arrangement are responsible for the persistent poverty of the rural population of LDC's. To this school of thought, land reform measures such as rental rate reduction, land redistribution, abolition of sharecropping, and minimum term leases are viewed as policy instruments that can improve development prospects. Others, however, disagree. Those of the "equal efficiency" school argue that the form of land tenure has no bearing upon allocative efficiency and would attribute the poverty of the agricultural sector of LDC's not to the prevailing land tenure arrangements but to their factor endowment—a large body of unskilled labor relative to land and capital. This school also believes that land reform proponents' arguments in support of reform are more often than not founded on normative welfare criteria rather than the positive criterion of economic efficiency.

In recent years an empirical dimension has been added to the debate in an attempt to resolve the controversy. Results have varied, but generally it has been found that tenancy is not necessarily less efficient than owner cultivation.

The theoretical arguments of the "equal efficiency" school as well as the empirical studies purporting to support this school seem to be seriously misleading. The limitations of their analysis stem from their failure to take account of the interactions and linkages of the agricultural and other sectors throughout the development process. It is contended that the "efficiency" of alternative land tenure arrangements and associated land reform recommendations cannot be analyzed out of the context of these intersectoral linkages and interactions. Land reform, and the choice of an optimum land tenure system, has implications not only for the efficiency of resource allocation in the farm sector but for the economy as a whole.

In what follows we review the literature sur-

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rounding the comparative efficiency controversy and explore the significance for allocative efficiency of three interrelated factors which have not been adequately dealt with in the comparative efficiency debate: the existence of positive transaction costs, the scarcity of entrepreneurship in LDC's and the effects of the form of factor remuneration on incentives. We conclude that in many circumstances land reform measures can improve intrasectoral and intersectoral resource allocation. Where relevant we demonstrate how our theoretical conclusions can be used to account for the results of empirical studies which indicate little, if any, difference in the comparative efficiency of the various forms of land tenure.

The Comparative Efficiency Controversy

In the literature on the comparative efficiency of the various forms of land tenure, attention has been primarily focused on the comparative efficiencies of four types of contractual arrangements: (*a*) owner cultivation, where land is a marketable commodity cultivated by the holder without aid of wage labor; (*b*) sharecropping, where the landlord leases land in return for a contractually stipulated portion of the output; (*c*) fixed rent, where landowners lease land for a predetermined rental charge per hectare; and (*d*) wage cultivation, where the landowner hires labor to cultivate his land for a predetermined rate of remuneration per unit of time. In particular, there is some contention about the efficiency of sharecropping as a form of land tenure. On the one hand, it is argued that sharecropping leads to a misallocation of resources (Adams and Rask, Bardhan and Srinivasan, Georgescu-Roegen, Heady, Issawi, Marshall, Shickele). On the other hand it is argued that differing land tenure forms lead to the same resource allocation (Cheung 1968, 1969a, 1969b, Reid). The implications of both schools with respect to the value of land reform is obvious.

The inefficiency argument can be illustrated diagrammatically as in figure 1. It is postulated that agricultural output is not altered by the vagaries of weather, pests, etc., i.e., agriculture operates in a world of certainty and, for simplicity of exposition, that the only inputs are land and labor. Furthermore, decisions with respect to resource allocation are made in an economic environment of perfect competition, which is tantamount to assuming that the

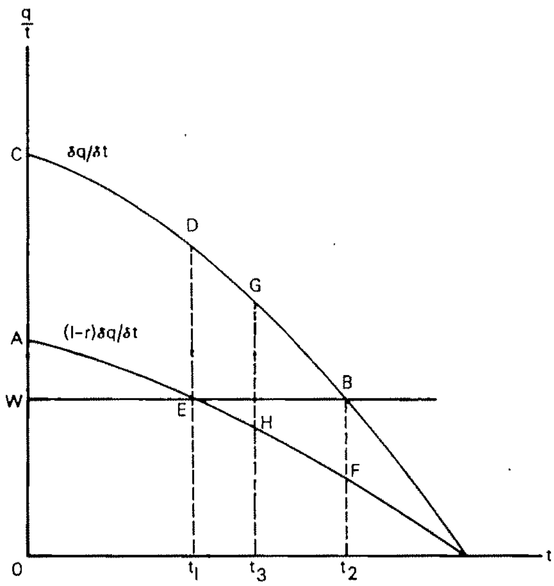

Figure 1. Labor input under share tenancy vs. owner cultivation

cost of negotiating and enforcing contracts is zero.

Let q represent output; t, labor input per unit of time; r, landlord's share of the product and hence $(1 - r)$ is tenant's share; h is the size of the unit of land which is assumed to be fixed; and W, the tenant's alternative earnings per unit of time, i.e., the market wage rate. The efficiency argument revolves around how much labor will be applied under sharecropping relative to, say, owner cultivation. Those who view sharecropping as inefficient see the sharecropping solution at t_1. Their argument is based on the fact that the sharecropper's marginal receipt, $(1 - r)\ \partial q/\partial t$, is equal to his alternative wage rate at t_1. They would argue that a rational sharecropper whose income-leisure preference dictated that he should work more than t_1 would do so by entering into, say, wage employment at the wage rate W which is, of course, strictly greater than marginal tenant receipt beyond t_1. The owner-cultivator would, however, apply his labor efforts to t_2, where his marginal receipt, $\partial q/\partial t$ equals his alternative rate of remuneration. Hence, it is concluded that sharecropping leads to an inefficient allocation of resources.

As recognized by the "equal efficiency" school, the validity of this generalization is questionable on theoretical grounds because it ignores the supply side of the model. Individual landlords and workers will demand for

each activity an amount at least equal to what they could earn in another activity. Since the same set of decision-making constraints obtain under each of the four forms of land tenure, it can be concluded that resource allocation will be the same for each (Cheung 1968, 1969a).

Thus, the mistake of those who saw sharecropping as inefficient was due largely to their use of partial equilibrium analysis. It becomes obvious when we look at the farm sector in a general equilibrium framework that in market equilibrium under perfect competition the four forms of land tenure must generate the same resource allocation. Assuming perfect competition ipso facto implies that the existing land tenure arrangements will be equally efficient. In view of this, one wonders why the debate has persisted along these lines. The questions which need to be asked are—given the typical LDC is characterized by market imperfections in both the factor and product markets, by population pressures, human and physical capital deficiency, and massive inequalities in the distribution of wealth and income—do these factors have implications with respect to the types of land tenure arrangements actually prevailing, and can those tenure arrangements be characterized as economically efficient? If not, can land reform improve allocative efficiency and if so, what type of land reform?

A comprehensive study of land tenure systems and the potential usefulness of land reform measures undoubtedly needs to take the above mentioned factors into account and answer the question. In the limited scope of this paper, however, we want to concentrate on what we consider to be a serious limitation of the equal efficiency school's analysis; namely, the strength of their conclusions as a foundation for policy recommendations is severely weakened by the partial nature of their analysis. Specifically, the "equal efficiency" school neglects the implications of intersectoral linkages and interactions for efficient resource allocation. As a result of the very nature of under-development, markets generally fail to make marginal intersectoral adjustments in resource allocation. The intersectoral allocation most conducive to development often has to be induced by various policy measures. Thus, although the market may function reasonably well in a particular sector, immobilities, imperfect knowledge, social dualism, etc., often prevent the market from distributing resources optimally among sectors. In such cases direct intervention in the market is often justified. In what follows, we argue that in many LDC's the prevailing intersectoral allocation of resources can be improved by land reform measures.

Transaction Costs and Allocative Efficiency

In the pure theory of share tenancy, Cheung (1968, 1969a) has shown that the landlord will stipulate and the tenant will agree to work t_2 amount of time (see figure 1), since at t_2 the tenant's income $0AFt_2$ equals his opportunity cost $0WBt_2$, given land area h and rental rate r. However, marginal tenant receipt, $(1 - r)\, \partial q/\partial t$, is less than the tenant's marginal opportunity cost W beyond t_1. There is little incentive for the tenant to put in as much work effort per unit of time between t_1 and t_2 as between 0 and t_1. Therefore, to ensure the tenant puts in an "honest hour" of work, the landlord has to supervise or police the work of the tenant. In addition to these contractual "enforcement costs" the landlord will also have to incur contractual "negotiation costs." Let the sum of these two costs be called "transaction costs." The assumption of competition among tenants does not eliminate the necessity of supervision of the tenant's work by the landlord. As argued by Alchian and Demsetz, competition among workers does not remove the incentive by workers to shirk if their marginal receipt is less than their marginal product. The landlord may sack an "inefficient" tenant, in which case he has to incur negotiation costs of searching for new tenants who also have similar tendencies to shirk labor beyond a certain point of production. Thus, enforcement costs are important even within a competitive environment. It is true that under share tenancy the landlord can gain by further land subdivision. However, this gain will be offset by increased transaction costs entailed in the negotiation and supervision of a greater number of contracts. It is possible that economies of scale exist in "transaction costs" in the initial stages of subdivision, so that a landlord may be faced with a U-shaped average transaction cost schedule.

That transaction cost can be significant under share contracts was recognized by Marshall, whose writings gave rise to the theory of inefficient resource allocation under sharecropping. He saw the landlord spending "much time and trouble either of his own or a paid agent, in keeping the tenant to his work" (p. 644). Cheung (1969b) quotes the stipula-

tions of sample fixed rent and share contracts from China giving the reader an insight into the sizeable amount of time which must go into negotiating tenancy contracts. He also notes that "the 'shirking' of labor input, which may exist in wage contract (also under share contract) without enforcing the input or output, is costly to prevent" (1969a, p. 67). Reid found that the cost of negotiating and enforcing share contracts in the postbellum South and Iowa was significant and that "Southern landowners closely monitored their tenants' work" (p. 428). Winters points out the Iowa landowners insisted that they be able to "enter upon said lands at all reasonable hours for purpose of examining the same and the manner in which said farm is being attended," obviously with the intention of monitoring tenants' labor input (p. 144). Thus in terms of figure 1 there is a cost attached to ensuring that the tenant works the stipulated amount of labor time t_2. As a result, depending on the income-leisure preferences of the landlord, only a fraction of t_1t_2 of the tenant's labor may be supervised by the landlord. A graphical exposition of this possibility is depicted below.

Figure 2 shows an upward-sloping marginal disutility of labor (i.e., an increasing marginal utility of leisure) schedule, S_m, and a downward-sloping marginal income from work schedule, dY/dm, of the landlord. The positive ordinate indicates the income per unit of management time supplied by the landlord and the abscissa indicates the number of hours required by the landlord to supervise the tenant's work beyond t_1 in figure 1. Maximization of utility by the landlord requires that the marginal benefit of supervision time be equal to its marginal cost, i.e., m^* in figure 2 will be the number of hours worked by the landlord. It is reasonable to assume that the number of hours spent by the landlord in supervision is less than that by the tenant in cultivating the soil, i.e.,

$$m = \alpha t, \; 0 < \alpha < 1 \tag{1}$$

where α is a fraction which may be a constant (as drawn in figure 2) or a variable. The value of α will depend on a variety of factors such as the scope for product and factor substitution and the effectiveness of law enforcement agencies in arbitrating contracts.[1] Once m^* is determined by the landlord, the number of hours worked by the tenant which require supervision, t^*, can also be determined.

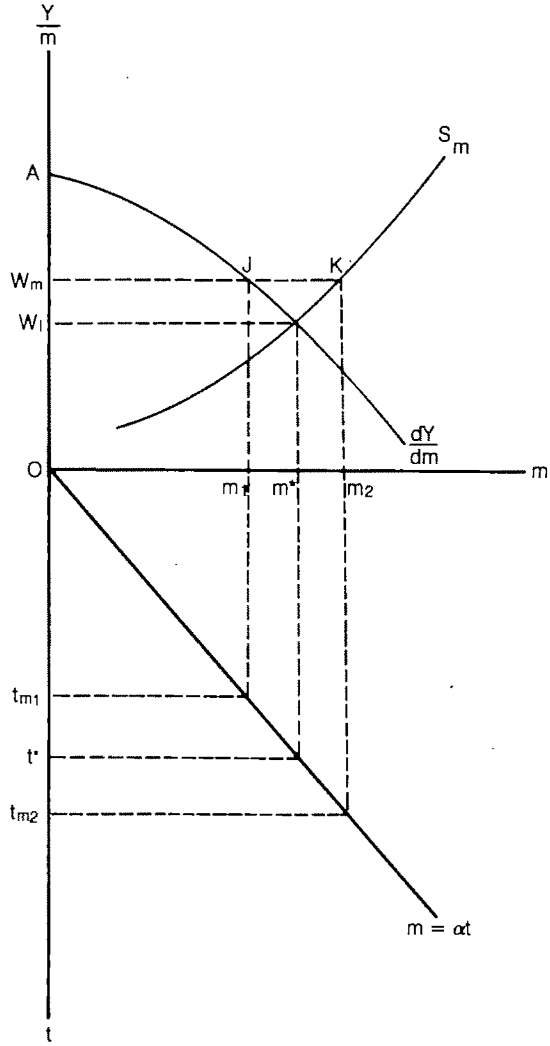

Figure 2. The determination of landlord supervision time

$$t^* = m^*/\alpha \tag{2}$$

In general, there is no presumption that t^*, the equilibrium level of supervised working time for the tenant, is necessarily equal to t_1t_2. Although on a different scale, figure 2 has been drawn to indicate that t^* would fall in the interval 0 to t_1t_2, for example, t_3 in figure 1. In figure 1, this is seen as a misallocation of resources since $\partial q/\partial t > W$.

It is conceivable that the landlord may be so well-off and the marginal income derived from supervising the tenant is so small that the S_m schedule lies above the dY/dm schedule for all

[1] Note the position of the dY/dm function will depend upon the value of α. Specifically, the marginal receipt of management time is inversely related to α.

positive values of m, in which case the landlord will leave the tenant to work to t_1 without supervision.

If we assume that alternative employment opportunities are available to a landlord in the industrial sector, to be symmetrical with the treatment of tenant labor, and that the landlord's alternative remuneration rate in the manufacturing sector is W_m in figure 2, then the supply curve of labor of the landlord is the broken line W_mJKS_m. He will work Om_1 hours supervising his tenant's work and work m_1m_2 hours off the farm at the going wage rate of W_m. In equilibrium, the marginal income from the farm is equal to the industrial wage rate, i.e.,

$$(3) \qquad W_m = r\frac{\partial q}{\partial t}\frac{dt}{dm} = \frac{r}{\alpha}\frac{\partial q}{\partial t} = \frac{dY}{dm}$$

If $t^*_{m^1}$, the amount of supervision time, is not in the interval t_1t_2, the tenant's labor is underutilized and agricultural output is not maximized.

Should $t^*_{m^1}$ be exactly equal to t_1t_2, the marginal condition, $\partial q/\partial t = W$, holds and resources are allocated efficiently. Note, however, the additional income accruing to the landlord *DEFB* in figure 1 due to supervision has not been procured without cost. Specifically, the opportunity cost of getting this increase in income is W_mm_1, which is directly traceable to the reliance upon sharecropping as a form of contractual arrangement. Of course positive transaction costs would prevail under wage contract and fixed rent as well.

Supervision costs would no doubt be higher under wage contract since all labor, 0–t_2 must be supervised as compared to t_2–t_1, under share contract. The supervision costs under fixed rent would result from the need to ensure soil fertility, farm equipment, and other properties are properly maintained. However, "negotiation costs" would undoubtedly be lower under wage contract and fixed rental relative to share contract as the market determines wage rates and rental rates.

Such supervision costs represent an economic waste in the sense that by altering property rights arrangements the same output could be obtained without employing scarce resources for policing purposes. The resources employed for supervision purposes under wage, share, and rental contracts represent "potential surplus labor" which would become redundant in the agricultural sector if land redistribution to the tiller was undertaken.

Transaction Costs and Empirical Studies

As noted above, a number of empirical studies appear to lend support to the "equal efficiency" school's conclusions (Ahmad, Bray, Hendry, Huang 1971, 1975, Ruttan). These studies have concluded there is little if any observable difference in output per hectare between farms cultivated by the owner and farms cultivated under share tenancy.[2] The implication of these results is obvious. Land reform would be of questionable usefulness for enhancing the efficiency of the agricultural sector in LDC's. However, just as the theoretical construct of the "equal efficiency" school ignores the intersectoral linkages and interactions of the development process, so do the empirical studies which seem to support that school's conclusion. Under our assumptions, even if the empirical evidence shows equal efficiency, land tenure arrangements other than owner cultivation involve an expenditure of human resources which could be made redundant in the agricultural sector by land redistribution to owner-cultivators. These resources could then be reallocated to other sectors.

Ignoring for the moment intersectoral allocative efficiency, our analysis has also shown that it is quite likely output under owner cultivation will be higher than under share tenancy because of the incentive to shirk labor under the latter form of land tenure. Under such circumstances if the tenant were to become the owner of the land through land reform measures, agricultural output would rise. Thus we would conclude that in many countries land reform, besides improving intersectoral resource allocation, would also

[2] The methodology by which the efficiency of the various land tenure systems is compared in these empirical studies leaves some doubt as to their usefulness in resolving the comparative efficiency debate. Differences or lack of differences in output per hectare of land in different locations under diverse climatic, institutional, and production conditions cannot be attributed to land tenure arrangements alone. A more acceptable test would be to compare productivity of the same plot of land before and after a change in land tenure, with "other things remaining equal." However, more often than not, other things do not remain equal after the introduction of land reform measures. For example, the size of an individual farm may be reduced as a result of land redistribution. The Japanese and Taiwanese experiences, however, leave little doubt that in many LDCs land reform appropriately carried out can benefit agricultural production and contribute to the economic development of the entire economy.

improve allocative efficiency within the agricultural sector. It is our latter conclusion that appears to be in conflict with empirical studies. However, we contend that because of a failure to account for the differential effects of risk on factor inputs, these studies understate the potential efficiency of land reform measures.

Let us assume tenants and owner-cultivators are risk averse. Under share tenancy risk is dispersed between the landlord and tenant in accordance with their respective shares. Under owner cultivation the entire risk is borne by the owner. Since it has been established that risk aversion results in a reduction in the equilibrium level of inputs (Batra, Batra and Ullah) why do the empirical studies not reveal a greater level of inputs and outputs under sharecropping? If the transaction costs associated with sharecropping lead to less than the contractually stipulated labor being supplied this might account for observations of little or no efficiency difference. The point is that the empirical studies may be reflecting the net result of two tendencies: (*a*) the tendency for labor to be shirked under share tenancy; and (*b*) the tendency for owner-cultivators to react to the greater level of risk, reducing inputs by more than sharecroppers.

In figure 1 let us assume that without uncertainty the landlord supervises the tenant only to the extent that he works t_3 units of time, i.e., the tenant shirks t_3t_2 labor time. Without uncertainty the owner-cultivator would work t_2 units of time. Hence the existence of transaction costs, in this example, has resulted in owner cultivation being more efficient than sharecropping. Now introduce uncertainty. The owner-cultivator, who reacts more strongly to the uncertainty element, will reduce his labor input more than will the sharecropper. For example, the owner-cultivator may reduce his labor input by t_1t_2 and the sharecropper by t_1t_3 with the result that both work t_1 units of time.

The introduction of transaction costs into the analysis of the comparative efficiency of the various land tenure systems has highlighted the fact that only owner cultivation involves no costs of supervision whereas wage contracts, share tenancy, and fixed-rent contracts entail either the costs of policing labor or the costs of ensuring that soil fertility, farm equipment, and other properties are properly maintained. Thus land reform in the direction of increasing the acreage under owner cultivation, provided individual farms attain a minimum size for efficient cultivation, would improve economic efficiency by eliminating the costs of enforcing contractual relationships between the principals (landlords) and the agents (tenants and farm hands).[3] As we have shown, it may also serve to increase agricultural output as has occurred in Taiwan, Japan, and parts of Africa and Latin America (Warriner, World Bank, Yang). Furthermore, we have shown the empirical studies which purportedly support the "equal efficiency" school may be of limited value as an attempt to resolve the comparative efficiency debate since they fail to take into account the net impact of transaction costs and differential risk reactions of cultivators under alternative forms of land tenure.

Continuing our analysis of land reform in the context of intersectoral relationships, we shall, in the following section, concentrate on the impact of land reform on the supply of entrepreneurial talent—the scarcest of resources in LDC's.

Land Reform, Entrepreneurship, and Economic Development

In the literature on land tenure systems and agricultural efficiency, exclusive attention is paid to the question of how much output is likely to be produced under different tenurial arrangements. It is contended in this paper, however, that the respective merits of alternative tenure systems should not be judged solely by how much farm output is produced, but also by the quantity of inputs necessary to achieve a given level of output.

In comparing the efficiency of the various land tenure systems and arriving at the conclusion that they are equally efficient, Cheung (1968, 1969a), by abstraction, neglected the crucial role played by entrepreneurship in the production process. Although Rao and Huang (1973) attempt to remedy this deficiency, their discussions are restricted to the explanation of the incidence of the different forms of tenurial systems in India and Malaysia and the connections between risk bearing, decision making under uncertainty and entrepreneurial functions in agricultural production. If the

[3] Of course there does exist management costs beyond contract negotiation and supervision. These other management costs have to be borne by landlord and owner-cultivator alike.

scope of analysis is broadened to allow for the transfer of entrepreneurs as well as workers between the agricultural and other sectors, land reform and the choice of a particular type of land tenure system may have ramifications for the development of all sectors of the economy.

Production in general requires land, labor, capital, other inputs and entrepreneurial talent. While the less developed countries may be deficient in land, or labor, or capital, the scarcest factor of production in these countries is likely to be entrepreneurs who are capable of motivating and mobilizing other factors of production, providing leadership, and working out plans for economic development and political and social reform. Thus the efficacy of various forms of contractual arrangements can be evaluated in terms of the amount of entrepreneurial talent which can be freed for reallocation to other sectors.

Table 1 indicates who, between the landlord and tenant, is responsible for supplying the various inputs under different forms of land tenure. Let agricultural production be a function of five variables:

$$Q = F(H, L, K, E, \epsilon),$$

where Q is output; H is land; L is labor; K, capital and other inputs; E, entrepreneurship; and ϵ, random variable. The application of the various inputs by the landlord and the tenant under alternative forms of land tenure systems can be schematically described as in table 1.

Under owner cultivation, the landlord provides all the inputs required for the cultivation and the management of the farm and bears the entire risks. Under wage contract, the landlord provides land, non-labor inputs, entrepreneurship, and assumes all the risks while the tenant provides only physical labor. Under a fixed rent contract, the tenant furnishes all of the inputs except land. Under share tenancy, the landlord provides land, the tenant supplies labor and risks are borne by both in proportion to their respective share of output. Non-labor inputs may be provided by either one or shared by both while the entrepreneurial input, although usually assumed by the tenant, may in part be supplied by the landlord. With land reform measures which transfer the land title to the tiller of the soil, the tenant in fact becomes the owner-cultivator and the entire production function is assumed by him. Hence the landlord is completely relieved to work elsewhere in the economy.

It is probably fair to say that entrepreneurial functions are more demanding in industry, government, and commerce than in agriculture, and that landlords are usually better educated and better trained than the tenants and hence possess more entrepreneurial talent. Be that as it may, any form of land tenure system which can free a portion of the society's stock of entrepreneurial talent (that portion engaged in contract negotiation and supervision) for reallocation to other sectors tends to promote a more efficient allocation of resources for the economy as a whole.

There are those who would argue that empirical evidence seems to indicate that the landlord class in some LDC's, although educated, do not exhibit entrepreneurial characteristics. We would argue that there are several explanations. Looking at the supply side, the landlord class's often very high levels of income have placed them on the backward bending portion of their supply of effort function. With land redistribution there will occur wealth redistribution which would impel the former landlord class to rely for income creation on their entrepreneurial abilities rather than their wealth. Looking at the other side of the coin, we would further argue, along with

Table I. Source of Inputs Under Alternative Land Tenure Systems

	Landlord					Tenant				
Tenure System	H	L	K	E	Risk Bearing	H	L	K	E	Risk Bearing
i. Owner Cultivation	+	+	+	+	+					
ii. Wage Contract	+		+	+	+		+			
iii. Fixed Rent	+						+	+	+	+
iv. Share Tenancy	+		+*	+*	+		+	+*	+	+
v. Land Reform						+	+	+	+	+

* A possible source of input

Habakkuk, that the highly skewed distribution of income in many LDC's depresses the demand for entrepreneurial talent. The economic size of domestic markets is small thus inhibiting the application of entrepreneurship to industrial pursuits. Those outlets for entrepreneurial talent which are available outside agriculture are often limited to the commerce sector. The redistribution of income associated with land redistribution, by enlarging the market for basic consumer goods, could create new outlets for entrepreneurial talent.

Drawing on the experience of Japanese development, which owed a great deal to the industrial entrepreneurs coming from the landowning gentry, W. A. Lewis observed that:

> a swift transformation of landowners and nobles into capitalists . . . resulted from the state buying out the feudal rights of the nobility and depriving them of their administrative functions; at the same time it also took over the debts of the feudal lords. Finding themselves with plenty of money (or rather government bonds), and no duties, some of the lords turned in the first place to banking and when in 1880 the government decided that it was ready to sell some of the factories which it had established for pioneering purposes, it found a ready market. This swift transformation of an old-type aristocracy into a new-type capitalist class was profoundly important in increasing the supply of entrepreneurship in Japan in the crucial last quarter of the nineteenth century (p. 237).

What is perhaps more important than the static gains from the redistribution of entrepreneurial talent between agriculture and other sectors is the dynamic gains which can be realized through (peasants) learning (management) by doing and new entrepreneurs emulating the more established entrepreneurs. It is significant that land reform which transfers the ownership of land to the tiller of the soil is likely to generate the greatest amount of X-efficiency (Leibenstein 1966) because the new owner-cultivator has all the incentive and motivation to do his best.[4] Thus land redistribution can augment society's stock of entrepreneurial talent.

Thus, viewing the problem as one of optimally allocating scarce management resources intersectorally, it is incorrect to argue that the various land tenure systems are equally efficient and that no social gains can be achieved by land reform. The geometric and mathematical treatment of the issue by Cheung (1968, 1969a) under highly simplified assumptions can result in policy inaction which leads to the undesirable result that the potential rate of development is not realized or to the positively detrimental result that the economy becomes further stagnated, making the development task even greater when appropriate policies are finally introduced.

Incentives and Agricultural Efficiency

While an optimal allocation of entrepreneurship between the agricultural and other sectors may expedite economic development, the incentive factor that is built into the various land tenure schemes may contribute to differences in efficiency in production even though the same quantities of labor and other inputs are applied to a given plot of land. It has been pointed out by Leibenstein (1966), based on both microeconomic and macroeconomic data, that improvement in allocative efficiency by eliminating market imperfections such as monopolistic and monopsonistic elements, tariffs, etc., can be expected to be quite small whereas improvement in "X-efficiency" due to motivation and incentive factors in production can be substantial. While his arguments have been applied mainly to production in the manufacturing sector, they may be equally valid in describing agricultural production. His main thesis is that due to the absence of a unique, mechanistic one-to-one correspondence between inputs and outputs and the inability to specify precisely the work effort to be provided by labor in wage contracts, there is considerable scope for improvement in output given the "same" quantity of inputs. Normally, the resources of a firm or of an economy are not "fully" utilized, i.e., they are not producing on the outer-bound production-possibility surface but are well below the maximum permitted by existing technology. The human element in the production process, be it entrepreneurship or workmanship, has to be motivated and economic or noneconomic incentives have to be provided in order to achieve the objectives or profit maximization, cost minimization, and production efficiency.

In terms of our analysis, Leibenstein's thesis can be interpreted to mean that the marginal productivity of labor, given a fixed plot

[4] To reduce the risks of being ruined by natural calamities confronting agricultural production—risks which can reduce the commitment of variable inputs (Batra, Batra and Ullah)—the government can enforce compulsory crop insurance or guarantee the farmer a minimum income.

of land, may vary over a fairly wide range. The incentives for the tenant to work hard are likely to be the least under a wage contract in comparison to owner cultivation, a fixed-rent contract, or a share contract. Let us assume that marginal product of labor is given by $T_0T'_0$ in figure 3 under a wage contract but by $T_1T'_1$ under the other types of land tenure system.[5] Under a wage contract, total output equals $0T_0AA'$ of which $0W_0AA'$ goes to labor, given that the alternative wage rate in industry for a tenant is $0W_0$.

Should an alternative form of tenancy be adopted, the marginal product of labor is shifted outward to $T_1T'_1$ because incentives for obtaining extra income are greater. Suppose the incentive factor under the share tenancy is proportional to his share of total income which is $(1 - r)$ of total output, where r is the share going to the landlord. Let BAT'_1 denote $(1 - r)$ times the marginal product of labor. The tenant will work up to $0A'$ voluntarily in order to maximize his income. Thus, in this example, share tenancy will produce a greater output than a system of wage contracts and the greater effort required of the sharecropper is rewarded by the additional income equal to W_0BA. The landlord will receive an income equivalent to BT_1CA, which may be greater than, equal to, or less than W_0T_0A, the area of which indicates the landlord's income under wage contract.

The cost to the owner-cultivator to shift out of agriculture to find work in industry is likely to be higher than that of the landless worker or sharecropper. The former's opportunity cost which equals, say, $0W_1$ in figure 3, can be expected to be greater than that of the latter's which equals, say, $0W_0$, due to the premium awarded to those capable of more complex decision making. Therefore, the owner-cultivator will work up to $0A'$. The yield per hectare may be the same under owner cultivation and share tenancy if the expected alternative income of the owner-cultivator is higher than that of the tenant. This may explain the empirical findings that agricultural productivity may not be lower under share tenancy than under owner cultivation (Ahmad, Bray, Hendry, Huang 1971, 1975, Ruttan).

In the case of fixed rent, the tenant is likely to work up to $0E'$ to maximize his income.

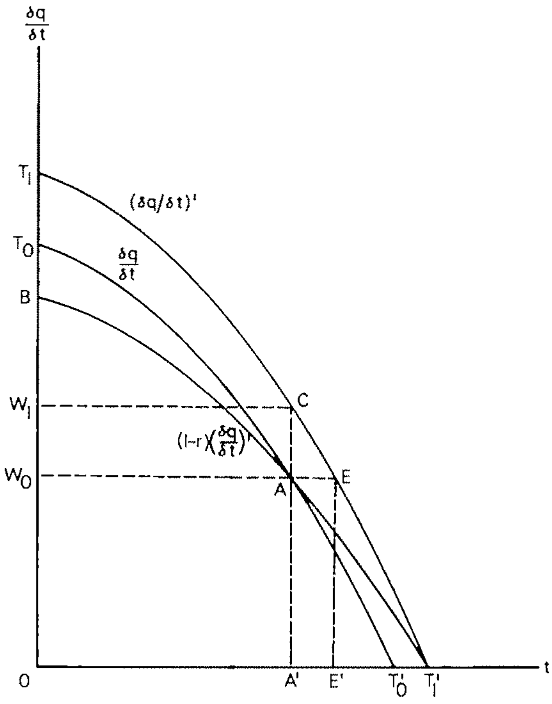

Figure 3. Land tenure and production incentives

However, due to the limited terms of a rental contract, a tenant on fixed rent is less motivated than an owner-cultivator to make capital investment which may permanently improve production. Furthermore, the landlord may be willing to receive an income less than W_0T_1E so as to compensate the tenant for shouldering all the risks involved in farming. Should there be a land reform which transfers the ownership of the land to the tenant and if his opportunities outside the farm were limited, the new owner-operator would work up to $0E'$ to maximize his income.

There are two aspects of agricultural production highlighted in this section. First, different land tenure schemes offer different incentives and motivation for work and hence the X-efficiency in production may be improved by land reform or choice of an appropriate land tenure system. Second, landlords and tenants may not face the same opportunity costs. In fact, the former attach certain utility to the ownership of land and the compensation required by the landlords for leaving the agricultural sector tends to be higher than that of the tenants who may be indifferent between jobs in industry or jobs on the farms.

[5] To overcome the lack of incentives in wage contracts it is possible that the marginal productivity of farm hands may be shifted upward by close supervision by the landlord.

Conclusion

We have shown that the efficiency of various forms of land tenure and hence the usefulness of land reform measures should not be analyzed out of the context of the changes within and interaction among the various sectors of a developing economy.

Different forms of land tenure are in effect different ways of combining resources owned by different parties. We have shown that, given the characteristics of LDC's, some of the prevailing forms of land tenure require the use of scarce resources which, by the introduction of land reform measures, could be made available to the nonagricultural sectors, resulting in material gains to society. This conclusion can be viewed as somewhat of a twist on the "surplus labor" theory in that the surplus labor is generated by altering the institutional framework in the farm sector and the surplus labor so created is not the traditional unskilled agricultural labor but an educated potential entrepreneurial class.

Where relevant, we have demonstrated that our theoretical results are compatible with empirical studies which indicate little or no productivity differential among the alternative forms of land tenure. The findings of these studies, as a foundation for policy recommendations on land reform measures, have to be reinterpreted in the light of our analysis.

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Macroeconomic Policy, Investment, and Urban Unemployment in Less Developed Countries

Walter Haessel

The two sector Harris-Todaro model, extended to include a government sector and aggregate demand, is used to analyze the effects on output, prices, and employment of policies designed to mitigate urban unemployment. An increase in aggregate demand will be inflationary even though output will increase. Government job creation will be inflationary, will stimulate manufacturing output, but may result in a decrease in agricultural output. Investment in agriculture will increase agricultural output, decrease manufacturing output, and decrease price level. Investment in manufacturing results in an increase in manufacturing output, agricultural output and employment will decline, and prices will fall.

Key words: LDC macroeconomic policy, rural-urban migration, two sector model, urban unemployment.

Widespread urban unemployment is recognized increasingly as one of the more pressing problems in many less developed countries. Much of the theoretical analysis of this problem is based on a two-sector, general equilibrium model introduced by Harris and Todaro (1970). The major contribution of the Harris-Todaro (H-T) analysis is to provide a consistent economic explanation for rural to urban migration in the face of open unemployment in the urban areas. Essentially, their hypothesis is that rural-urban migration continues until the expected urban wage (downward-rigid actual urban or manufacturing wage multiplied by the probability of being employed) equals the rural or agricultural wage rate, which is lower than the actual urban wage rate. The net result is an equilibrium characterized by urban unemployment. The empirical relevance of their model and all subsequent extensions depends on the appropriateness of the assumption that migration depends on both rural-urban wage differentials and urban job opportunities or employment probabilities. Recently Todaro reviewed empirical country studies relevant to these issues and concluded:

> Evidence from Brazil, Jamaica, India, Taiwan, Tanzania, Kenya, and Sierra Leone seems to support (with varying degrees of scientific validity) the proposition that rural-urban migration should be viewed within an "expected" income context that emphasizes the interactive effects of wage differentials and urban unemployment rates on intersectoral labor mobility. (p. 384)

On the other hand, Godfrey concluded that certain evidence from Ghana was not consistent with the H-T migration assumption. However, Haessel (1977) has reanalyzed the data utilized by Godfrey and argues that these data are, in fact, not inconsistent with the rural-urban migration hypothesis utilized by Harris and Todaro. Hence, the empirical evidence available at this time seems to support the H-T migration hypotheses.

In this paper, the H-T model is extended by incorporating aggregate demand and government employment demand. This extension permits a broader analysis of the implications for urban unemployment of macroeconomic policies such as stimulating aggregate demand, increasing government employment, and changing the minimum wage rate. Although the model is static, the implications of investment in agriculture and manufacturing for urban unemployment and sectoral output and

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employment levels are examined. The target variables considered include the domestic price level and output and employment levels in agriculture and manufacturing.

The model is developed in the following section. The implications of the various policies are analyzed in the third section of the paper. A number of the conclusions depend on the magnitudes of certain data and parameters, and available empirical evidence is summarized. The conclusions are summarized in the final section. The implications of certain assumptions for the conclusions are also analyzed in that section.

The Model

Consider a small, open economy which produces agricultural and manufacturing goods. Real domestic output, X, valued at constant world prices is

$$(1) \qquad X = A + M,$$

where A and M denote agricultural and manufacturing output at world prices. Aggregate demand, Y, in current domestic prices is

$$(2) \qquad Y = C + Wg + G + B,$$

where B is the balance of trade (exports minus imports), Wg is government expenditure on employment and G denotes exogenous (government) expenditure on goods and services, all in current prices. G and Wg may be for capital formation or provision of government services. Consumption expenditure in current prices is given as

$$(3) \qquad C = \beta Y,\ 0 < \beta < 1.$$

Using the absorption approach to the balance of payments (Johnson), in current prices, B = receipts − payments = $PX - (C + Wg + G)$, where P is the domestic price level. In the absence of international capital flows, balance of payments equilibrium is maintained by adjustment of the domestic price level (which is equivalent to the price of foreign exchange in terms of domestic currency). In equilibrium $B = 0$, or

$$(4) \qquad PX = C + Wg + G = Y.$$

Since trade is permitted, the relative prices of agricultural and manufacturing output are the relative prices prevailing in world markets and are taken as exogenous.[1]

Production of agricultural and manufacturing goods requires labor and capital as inputs. Thus:

$$(5) \qquad A = A(a, k);\quad A_a, A_k, A_{ak} > 0;\quad A_{aa} < 0,$$

where a and k denote inputs of labor and capital, respectively, and subscripts denote partial derivatives. Similarly,

$$(6) \qquad M = M(m, j);\quad M_m, M_j, M_{mj} > 0;\quad M_{mm} < 0,$$

where m and j denote inputs of labor and capital in manufacturing.

The labor market is based on an H-T rural-urban migration analysis. A fixed labor force (L_o) is distributed among agricultural employment (a), manufacturing employment (m), unemployed urban labor (u), and government employment (g). Thus:

$$(7) \qquad L_o = a + m + g + u.$$

Employees in manufacturing and government receive an institutionally-fixed nominal minimum wage W. This differs from the assumption in H-T, where a fixed real wage rate is assumed. An institutionally fixed nominal wage seems more realistic than assuming a fixed real wage. Data summarized by Smith (tables 1, 2, and 6) indicate that real wage rates do decline in some LDC's. Furthermore, we are interested in the question of policy regarding minimum-wage legislation which is usually framed in terms of nominal wage rates. Employment in manufacturing is determined such that the marginal value product of labor is not less than W. Thus,

$$(8) \qquad PM_m \geq W.$$

Government employment, g, is considered to be a policy instrument.

Following H-T, it is assumed that the minimum wage rate does not apply to agricultural employment, and rural laborers will migrate to the urban areas in search of employment as long as the expected urban wage is greater than the marginal value product of agricultural employment. The expected wage is the urban wage rate multiplied by the proportion of

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[1] A sufficient condition to guarantee this simplifying assumption is a small open economy with liberal trade policies and without exchange controls. The other frequently used extreme assumption which is even more unrealistic is to assume a completely closed economy. H-T used the latter assumption. Bhagwati and Srinivasan reanalyzed the H-T model with both assumptions and found their conclusions were invariant to the assumption. The implications of an overvalued exchange rate and exchange controls for the conclusions of the paper are discussed in the final section.

urban laborers gainfully employed in either government or manufacturing. H-T assumed a random job selection process whereby every member of the urban labor force has an equiprobable chance of being employed. If it is further assumed that the minimum institutional wage is too high to permit full employment of all laborers at the legal wage rate, then the inequality in equation (8) can be replaced by an equality, and

$$(9) \qquad PA_a = W\, L^*/L,$$

where $L = g + m + u$ is the urban labor force, $L^* = g + m$ is urban employment and L^*/L is the urban employment rate or probability of being employed.

The same equilibrium condition is obtained by assuming that the employed urban workers share their earnings equally with the unemployed (urban laborer) members of their extended families. Then rural workers will be able to increase their income by migrating to the urban areas if the total urban wage bill divided by the total urban labor force (employed and unemployed) exceeds their rural income.

The model contains nine equations and nine endogenous variables: X, A, M, Y, C, P, a, m, and u. In addition, there are five instrumental variables: G, g, k, j, and W. The model can be reduced by substituting to eliminate irrelevant variables. One reduced system of equations is as follows:

$$(10) \quad bP\,[A(a,k) + M(M,j)] = Wg + G,$$

$$(11) \qquad L_o = a + m + g + u,$$

$$(12) \qquad PM_m = W,$$

and

$$(13) \qquad PA_aL = WL^*,$$

where $b = 1 - \beta$. This reduced model contains four equations, four endogenous variables (P, a, m, and u) and five exogenous variables (g, G, W, k, and j). Equation (10) is the equilibrium condition for the commodity market and states that aggregate supply is equal to aggregate demand, both measured in current prices. Equations (12) and (13) determine employment in manufacturing and agriculture, respectively, and (11) is the overall labor market equilibrium condition.

As formulated, government activities are nonproductive. Changes in government employment in state-owned agricultural or manufacturing firms (which would be productive) are not considered. Since a and m are endogenous in the model, any increase in government employment in either of these areas would be offset by a concomitant decrease in private employment.

Transportation, communication, and other services are often utilized in the production of final output, and improvement in the quality of these services would amount to an upward shift in the respective production functions.[2] Certain government activities (such as the armed forces) are nonproductive. Finally, governments invest in social overhead capital such as irrigation systems and rail lines. While productive in the long run, the projects usually do not become productive until after they are completed. Thus, the "demand expansionary" effect of government or private investment expenditures can logically be analyzed separately from the "output expansionary" effect. In this analysis, government activities are considered nonproductive in the contemporaneous period. These activities can be viewed either as investment expenditures which have payoffs in later periods, or as unproductive (make-work) projects. The output expansionary effects of investment are considered separately.

This model is used to analyze the effects of certain policies on the level of prices, outputs, sectoral employment levels, and urban employment. The policy instruments are government demand for goods and services, government job creation, the minimum wage level, and investment in manufacturing and agriculture.

Policy Implications

The qualitative effects of changes in the instruments on the target variables are summarized in table 1. For the targets of total, manufacturing, and agricultural output, and for

[2] To the extent that transportation and other services provided by government are consumed directly as final goods, their production should be included in final output. One could specify a government production function as $E = E(g, G)$. Then (10) would be modified as $b[P(A + M) + \lambda E] = Wg + G$, where λ is the share of government services consumed directly as final output. Logical consistency, however, would require that the production functions for A and M include government services as arguments. This would also require that value added instead of total output be used in measuring the output of the agricultural and manufacturing sectors. Including intermediate inputs greatly complicates the analysis. Haessel (1971), in a different context, presents a model of an LDC involving purchased intermediate manufacturing inputs in agriculture and purchased intermediate agricultural inputs in manufacturing. The model becomes very complex and most policy questions are indeterminate.

Table 1. Summary of Consequences of Changes in Policy Instruments

Target Variable	Instrument: Aggregate Demand G	Government Employment g	Minimum Wage W	Agricultural Investment k	Manufacturing Investment j
Total output X	+	+	−	+	+
Manufacturing output M	+	+	−	−	+
Agricultural output A	+[a]	?	−[a]	+	−[a]
Price level P	+	+	+	−	−
Manufacturing employment m	+	+	−	−	?
Agricultural employment a	+[a]	?	−[a]	?	−[a]
Level of unemployment u	−[a]	−[b]	+[a]	?	?
Rate of urban unemployment u/L	−	−	+	?	?

Note: The +(−) signs indicate the target variable moves in the same (opposite) direction as the instrumental variable. The ? indicate the qualitative results depend on the magnitudes of the data and parameters.

[a] A sufficient but not necessary condition is that the absolute value of the elasticity of demand for labor in manufacturing $|\epsilon|$ is less than the ratio of employment in manufacturing and government divided by employment in manufacturing $|\epsilon| > (m+)/m$. The empirical evidence is consistent with this condition.

[b] Reasonable values for the data and parameters indicate a decrease although it is not certain.

manufacturing and agricultural employment, increases are desirable. However, decreases are desirable for the level and rate of urban unemployment. In the context of a small country with flexible exchange rate, domestic price increases would imply a depreciation of the external value of the country's currency and would be viewed undesirable by many people for political, if not for economic, reasons.

The results in column 1 for the consequences of an exogenous increase in aggregate demand are derived in detail. The results in the remaining columns, although derived in the same way, are discussed heuristically. Some of the conclusions depend on the magnitudes of certain data and parameters, and the available empirical evidence is summarized.

Aggregate Demand, Government Employment, and Minimum Wages

To derive the effect of an exogenous increase in aggregate demand, differentiate equations (10) through (13) totally with respect to G to obtain

$$(14)\quad \begin{bmatrix} \gamma & PbA_a & PbM_m & 0 \\ 0 & 1 & 1 & 1 \\ M_m & 0 & PM_{mm} & 0 \\ A_aL & PA_{aa}L & PA_a - W & PA_a \end{bmatrix} \begin{bmatrix} P_G \\ a_G \\ m_G \\ u_G \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix},$$

where $\gamma = b(A + M) > 0$, and the subscript G indicates the total derivative of the variable with respect to G (e.g., $P_G = dP/dG$), and other subscripts denote partial derivatives. Let $P = W = 1$ by arbitrary choice of units. It can be shown that the determinant of the 4×4 coefficient matrix in equation (14) (denoted Δ) is negative.

Expanding by the last column, $\Delta = bM_m^2 A_{aa}L + bA_a^2M_{mm}L - \gamma A_{aa}M_{mm}L + \gamma A_aM_{mm} + bA_aM_m(1 - M_m)$. All terms are negative except the last, which is zero, because by choice of units $M_m = 1$ (see equation (12)).

Using Cramer's rule,

$$(15)\qquad P_G = M_{mm}(A_a - A_{aa}L)/\Delta > 0,$$

since M_{mm} and A_{aa} are negative and A_a is positive. Thus, an increase in aggregate demand will result in an increase in the aggregate price level. From row 3 of (14) it follows that $m_G = -P_GM_m/M_{mm} > 0$, and employment and output in manufacturing will increase. It can be shown

$$(16)\qquad a_G = (M_m + A_aM_{mm}L)/\Delta.$$

The sign of a_G depends on the sign of $M_m(1 + LA_aM_{mm}/M_m) = M_m(1 + L^*/m\epsilon)$, where $L^* = m + g$ is urban employment, and

$$(17)\qquad \epsilon = \frac{\partial m}{\partial W}\frac{W}{m} = \frac{M_m}{mM_{mm}}$$

is the wage elasticity of employment in manufacturing. (Recall $W = 1$ by choice of units). A necessary and sufficient condition to guarantee $a_G > 0$ is that $|\epsilon| < (m + g)/m$. In other words, employment in agriculture will increase in response to an increase in aggregate demand if the wage elasticity of manufacturing employment is less (in absolute value) than the ratio of government plus manufacturing employment to manufacturing employment. This condition is likely to be satisfied since the empirical evidence is consistent with the hypothesis that manufacturing employment demand in LDC's is wage inelastic. The wage elasticity of employment (ϵ) in manufacturing has been estimated for a number of LDC's, using different specifications.[3]

Finally, since both manufacturing and agricultural employment increases, the level and rate of urban employment must decrease. These effects are summarized in column 1 of table 1.

Using the same procedure to analyze the effect of an increase in government employment, it can be shown unequivocally that prices will increase.[4] As a consequence of this increase in prices, the real wage rate in manufacturing falls and employment and output in manufacturing will increase. It is impossible to determine a priori the effect of a change in government employment on agricultural employment or output. It can be shown that

$$(18) \quad u_g = [m_g(1 - Q) - P_g L^* - 1]/Q,$$

where $Q = A_a - LA_{aa} = (L^*/L)\,[1 - L/(\Theta a)]$, and Θ is the wage elasticity of employment in agriculture. A sufficient, but not necessary, condition for a decrease in the level of urban unemployment as government employment increases ($u_g < 0$) is than $Q > 1$. Alternative values of Q are given in table 2 for plausible values of Θ and the data. It is clear from this table that if Θ is "large" in absolute value, the unemployment rate in the urban area is in excess of 10%, and at least 60% of the labor force is employed in agriculture, it is possible that $Q < 1$ and the necessary (but not sufficient) condition for $u_g > 0$ is fulfilled. However, it seems unlikely that will be the case and the level of unemployment will probably decline. Even though the level of urban unemployment may increase, it can be shown that the rate of urban unemployment will decline. These results are summarized in column 2 of table 1.

An increase in the nominal minimum wage rate will cause an increase in the real wage rate, but employment and output in manufacturing will decline. As output decreases, prices will rise. However, a given percentage increase in the nominal minimum wage rate will result in an increase of a smaller percentage in the aggregate price level. Consequently, the real wage rate will increase and employment and output in manufacturing will decline. The increased real wage rate in the urban areas creates an incentive for urban-rural migration. A reduction in the rate of urban employment works in the opposite direction by reducing the expected real urban wage, but this will not be enough to offset the increased real wage rate if the wage elasticity of manufacturing employment demand (ϵ) is less than the ratio of manufacturing plus government employment to manufacturing employment. Since this is consistent with the empirical evidence, agricultural employment and output will probably decline. An increase in the minimum wage rate will result in an increase in the rate of urban unemployment. Although it is theoretically possible for the absolute level of unemployment to decrease if agricultural employment increases, this seems unlikely even if agricultural employment increases. The decline in manufacturing output will be large enough so that the level of aggregate output valued at world prices will fall even if there is an increase in agricultural output. These results are summarized in column 3 of table 1.

Effects of Capital Accumulation

There are two aspects to be considered in appraising the effects of the accumulation of cap-

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[3] The following summary indicates the order of magnitude.

Country	Wage Elasticity (ϵ)	Source
Kenya	−0.736, −0.761	Harris and Todaro (1969, pp. 35–36).
Kenya	−0.52	King (p. 72)
Argentina	−0.36	Eriksson (p. 61)
Brazil	−0.72	Eriksson (p. 61)
Colombia	−0.99	Eriksson (p. 61)
Costa Rica	−0.67	Eriksson (p. 61)
Mexico	−0.87	Eriksson (p. 61)
Mexico	−0.514, −0.586	Isbister (pp. 34–35)
Puerto Rico	−1.14, −0.94	Reynolds and Gregory (p. 100)

In addition, Steel and Ahiakpor (tables 5 and 6) estimated wage elasticities of employment for 12 industries in Ghana based on 4-digit ISIC groupings, using two different specifications. Only three of their twenty-four estimates of ϵ were < -1.

[4] Detailed derivation of this and subsequent results are available on request from the author.

Table 2. Values of Q for Different Values of the Data and the Wage Elasticity of Employment

Urban Unemployment Rate (100u/L)	Percentage of Labor Force in Agriculture (100a/(L + a))	Wage Elasticity in Agriculture (θ)			
		−0.5	−1.0	−1.5	−2.0
25%	80%	1.13	0.94	0.88	0.84
15%	80%	1.28	1.06	0.99	0.96
10%	80%	1.35	1.13	1.05	1.01
25%	70%	1.39	1.07	0.96	0.86
25%	60%	1.76	1.25	1.09	1.01
15%	70%	1.58	1.21	1.09	0.97

Note: Turnham and Jaeger (table III.2) have tabulated urban employment rates for twenty-two countries. The highest urban unemployment rate is recorded for Algeria (24.7%) and only three countries had unemployment rates in excess of 15%. Turnham and Jaeger also tabulated the percentage of the labor force in agriculture for twenty-one countries (table II.6). Only two of these countries had over 70% of the labor force in agriculture (India and Thailand with 74% and 84%, respectively). No empirical evidence is available on θ, but the values considered in table 1 seem to cover the plausible range. Although it is not impossible, it seems unlikely that $Q < 1$ for many countries. For example, assuming $\theta = -2$, Thailand with 84% employed in agriculture and an unemployment rate in Bangkok of less than 4% satisfies the condition $Q > 1$, as does Algeria with 58% employed in agriculture and an urban unemployment rate of 25%.

ital in agriculture and manufacturing: the short-run effect of a change in the flow of investment expenditure on aggregate demand, and the longer-run effect of the change in the stock of capital on equilibrium values of prices and employment. The short-run effects of an increase in aggregate demand are discussed above, and now we consider the effects on the equilibrium values of the endogenous variables of the changes in capital stock. The capital formation could also be in the form of government employment of labor on capital formation projects. The short-run flow effects of such projects have been analyzed above.

Investment in agriculture would increase agricultural output and this increase would result in a decline in the absolute price level. The reduction in prices would increase the real wage rate, resulting in a decline in the level of employment in manufacturing. The expected urban real wage rate might increase or decrease depending on whether the rate of urban employment decreased proportionately more or less than the proportionate increase in the wage rate. Similarly, it is not clear if the real wage rate in agriculture will increase or decrease. The investment will increase the marginal product of labor, but this will be offset, at least in part, by the falling price level. The net result will be that employment in agriculture might increase or decrease. If employment in agriculture decreases, both the absolute level and rate of unemployment will increase. Employment in agriculture will increase if the marginal product of labor increases sufficiently as a consequence of the investment. Thus it is important that "labor-using" investments in agriculture be undertaken in order not to exacerbate the unemployment problem. By labor-using investment, we mean investments that have the tendency to raise the marginal product of many or all agricultural laborers. Investments which qualify are such things as improved road systems, irrigation schemes, and technological improvements such as investments in the development and distribution of new seeds and fertilizers. After reviewing the empirical evidence, Johnston and Cownie concluded that "the seed-fertilizer revolution . . . offers the possibility of absorbing a considerable fraction of the growing labor force into productive employment" (p. 579).

Investment in manufacturing will result in an increase in manufacturing output. This will cause the absolute price level to fall and the modern sector real wage rate will increase. As a consequence of the investment, the marginal product of labor will also increase so the level of manufacturing employment may either increase or decrease. Employment in agriculture will decline if employment in manufacturing increases, since both the real wage rate and the probability of obtaining a modern sector job increase. Agricultural employment will probably decrease even if the level of employment in manufacturing decreases, provided the latter decrease is not too large. A sufficient condition to guarantee this result is that the absolute value of the wage elasticity of demand for labor in manufacturing is less than the ratio of manufacturing plus government employment to manufacturing employment. Since available empirical evidence suggests this is the case, it is highly likely that agricultural employment will decline. However, it is

not clear what will happen to the level or rate of unemployment if manufacturing employment increases.

Summary and Qualifications

A model has been developed for a small, open dual economy which has a commodity market and labor market. Agricultural and manufacturing goods are traded in the commodity market at fixed (world) terms of trade. Using the H-T rural-urban labor migration hypothesis, urban unemployment has been explicitly incorporated into the model. The policy instruments considered are changes in aggregate demand, government employment, institutionalized urban wage rate, investment in manufacturing, and investment in agricultural production. The target variables examined were the price level and sectoral output and employment. Under the assumptions of this model, the following conclusions are derived.

With the exception of the minimum wage rate, an increase in any of the instruments considered will result in an increase in total output valued at world prices. An expansionary policy of increasing aggregate demand will be inflationary; but if governments "hold the line" on wage increases, this will result in an erosion of the rural-urban wage differential and lead to an increase in both rural and urban employment and output. An expansionary-inflationary policy is the only policy that guarantees urban-rural migration and alleviates pressures on urbanization. An increase in the urban minimum wage level and an expansion of the capital stock in manufacturing will guarantee increased urban-rural migration. The only policies that will ensure a reduction in both the level and rate of unemployment among the current urban residents are the expansionary policy and government job creation. The latter policy, however, might result in a reduction of agricultural employment and output and increased migration to the urban areas, partly offsetting the initial reduction in urban unemployment.

Labor-absorbing investment in either agriculture or manufacturing can result in a reduction of unemployment. However, investing in either manufacturing or agriculture separately may lead to a decline in employment in the other sector. Pursuing either of these separately might not eliminate unemployment. This suggests that some sort of balanced approach should be used, or the investment should be combined with an expansion of aggregate demand to prevent the real urban wage rate from rising.

The foregoing analysis has been based on a smoothly functioning economy with only one rigidity, the nominal minimum urban wage. In LDC's, however, there are other important rigidities in the short run. For example, production functions are not continuous and twice differentiable. This empirical observation does not necessarily invalidate analyses such as the above. However, because of "stickiness" in the economy, the conclusions must be viewed in a longer-run context, even though this is a short-run model. For example, if sufficient investment occurs in agriculture, employment and output in agriculture will eventually rise, *ceteris paribus*. The "sufficient" is required to account for nondifferentiability (corner solutions) in the production functions, and the "eventually" is required to account for short-run rigidities. The foregoing is a standard caveat that should be applied to any short-run analysis.

Two of the most crucial assumptions in the above analysis are the assumptions of a fixed nominal minimum wage and balance-of-payments equilibrium with a freely convertible exchange rate. The former assumption is crucial to the conclusions. If labor manages to maintain a constant real wage, many of the above conclusions will be reversed. The freely convertible currency assumption simplifies the analysis because the terms of trade between agriculture and manufacturing can be taken as exogenous. In a model with an overvalued currency and exchange controls, the terms of trade are endogenous and move in favor of the imported good as the domestic currency becomes relatively more overvalued. Since in the above model the domestic price level is tied to the price of foreign exchange in domestic currency, any policy that results in a domestic price increase amounts to a depreciation of the external value of the currency. If the currency is overvalued with a fixed exchange rate and exchange controls, a price increase results in the currency becoming relatively more overvalued and the domestic terms of trade would move in favor of the imported good (usually manufacturing). To what extent the above conclusions will be affected by an overvalued currency and exchange controls is an empirical question. A theoretical model with an overvalued ex-

change rate would be considerably more complicated than the above model, but empirical and theoretical research in this area would be useful.

Finally, the above analysis has been a short-run analysis focusing on the effects of policies on the level and rate of urban unemployment. The effects of investment in manufacturing and agriculture have been examined, but the long-run determinants of the levels of saving and investments have not been discussed. The expansionary-inflationary policy discussed will result in a redistribution of income from urban workers in favor of capitalists, and this undoubtedly will affect investment and savings decisions. It is not clear what the long-run effects of such a policy would be.

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Agriculture's Three Economies in a Changing Resource Environment

Harold F. Breimyer

For many years abundant and relatively inexpensive industrial raw materials contributed to a resource environment favoring industrialization of U.S. agriculture. Their gradual depletion and rising prices now create a counter pressure. The pace of industrialization has slowed, with different manifestations in the three economies of agriculture—crops, livestock, and marketing. The economics of extractive industries, a subject long neglected, will henceforth be an integral part of the economics of agriculture. Cited here are conceptual formulations the author published in a precursor article of 1962, formulations that go back to the "empty economic boxes" and the writings of Joan Robinson.

Key words: Impact of resource depletion, industrialization of agriculture, raw materials.

A half century ago three giants of economics contended in the language of "empty economic boxes" about the meaning of increasing, constant, and decreasing returns (Clapham, Pigou, Robertson).[1] They thereby set in motion new channels in the evolution of economic thought. As often happens with precursors, they doubtless did so without prescience.

As also is not rare, the essence of their argument remains with us yet. It applies to modern agriculture, for the configuration of its returns function has much to do with productivity and other attributes of agriculture under changing—tightening—conditions of access to the industrial resources on which today's technology relies.

To give more clues in advance to how the logic of this paper will be developed, the three kinds of returns help to explain the differences between the land-based and the industrial aspects of modern agriculture. Those differences were the subject of my "Three Economies" article published in 1962. At that time industrialization was proceeding apace and increasingly giving its imprint to agriculture. The essence of the 1962 article will be reviewed briefly. Since then, as also will be recounted here, a slow reversal has begun. Industrialization has begun to ebb. Although changes are still scarcely perceptible and occasionally denied, they are significant and, some would say, ominous.

Moreover, insofar as industrial features of agriculture have faded, the cause lies not in industrial processes as such and definitely not in institutional structure, but in a consideration that has largely been neglected or taken for granted; namely, the economics of the extractive sector of the economy. An agriculture that relies on petroleum, phosphate rock, and dozens of metals is implicitly subject to the situation in that sector. Growing scarcity and rising cost of those materials constitute a changing resource environment for agriculture.

A neglected sector is not often theorized about. The three economists referred to above did not explain extractive economics very well, nor have many of their successors. A few notes on the distinctive features of the economics of extraction, and lessons to be drawn for our day, will conclude this article.

Increasing Returns

Of the three categories of returns about which Clapham, Pigou, and Robertson contended, the center of attraction was increasing returns. Until two or three generations previous to their time, Western economies were domi-

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[1] In reality, Robertson termed Clapham and Pigou giants and himself a mere David.

nated by agriculture. Early economic thought had an agricultural bias. The pattern of returns in agriculture was not in question. It was decreasing or, better said, eventually decreasing. Still, in our day, the subtle inferences to be drawn from factor combinations that eventually are less yielding occupy the minds of savants.

Increasing returns are of another genre. Imaginative thinkers were fascinated by them. They also were perplexed. Returns that do not (eventually) decrease pose such annoying questions as, "where, if ever, can equilibrium be established?" They also offer a hopeful note to which economists of the "dismal science" school were unaccustomed.

Emergent Theory

Worth brief comment are the directions subsequently taken by economic theory. One is now known as industrial organization. Sraffa and Robinson in England and Chamberlin in the United States took note of human ingenuity in devising institutional arrangements that would make returns curves turn down (and cost curves up), thereby improving favored firms' chances to make a protected profit. Theirs was the fertile exploration into imperfect competition. In agricultural economics in the United States today the foremost exponent is Willard Mueller.

The other direction came to be known as economic development. The gradual emergence of this school is a story of itself. The essential optimism of increasing returns gave it impetus. Progress was slowed initially by picayune disputes over details such as the nature and significance of capital goods—their lumpiness and the meaning of length of time.[2] Robertson clarified a bit by introducing the idea that, "*given time,* methods of technique and of organisation are capable of improvement" (p. 146). (Page references are to the most convenient source of the three articles, Stigler and Boulding.) A few years later Allyn Young sprung the whole subject loose from the shackles of individual-firm thinking. In an article significantly titled "Economic Returns and Economic Progress" he observed that "the mechanism of increasing returns [arises from] the progressive division and specialisation of industries. . . . What is required is that industrial operations be seen as an interrelated whole. . . . In this circumstance lies the possibility of economic progress" (p. 539).

Two Robinsonian Models

The ultimate connection between increasing returns and development was set forth later by Joan Robinson in a perceptive 1962 article. She began by outlining two models, one entirely undeveloped and the other fully developed. The first is primitive and grim. Mankind subsists on whatever means are natively available. Human institutions such as markets are inapplicable. If an exchange price is used it is conventional.

The opposite model, the ultimate in development, is exclusively capital using. Clapham had initially suggested that increasing returns were the "economies of an organised industry" (p. 123) and Robinson now posited a fully organized economy. In it all factors of production are internally produced to human specification. Paradoxically, in such an economy, viewed without time as a constraint, returns would not be increasing but constant. Thus is refuted, at least conceptually, Clapham's claim that "constant returns . . . must always remain a mathematical point, their box an empty one" (p. 125). Constancy of returns is sufficient for unbridled hope.

The Robinsonian industrial model can be characterized also in terms of mobility and divisibility of resources. In her model of a totally industrial economy, all resources are perfectly mobile and divisible. Mishan had made mobility-divisibility a reference point in his welfare economics. I later borrowed the coinage in interpreting structural trends in marketing farm products (1976). As a simple illustration, both the location of the processing of those products and the competitiveness of local trading are influenced incisively by the mobility of materials and by their divisibility—the ease of their differentiation.

Manifestly, Robinson's industrial economy of mobile and divisible resources in which everything including human skills can be tooled to man's instruction is a halcyon prospect. It is the ultimate in development; it is the goal, however remote and elusive, to which measures in economic development are directed.

[2] Amazing to our era, Clapham wrote, "Economics . . . is not concerned with geological time. . . ." (p. 121).

We all want to control our destiny for richer reward.

Two Models for Three Economies of Agriculture

For my 1962 "Three Economies" study, I drew on Robinson's models, paraphrasing them in terms that the first describes the "primitive state, marked by the simplest economic pursuits." It is "an economy governed entirely by fixed, predetermined factors of production." In the industrial model, by contrast, all factors of production are internally produced. It is "a totally self-contained and self-sustained economy in which no factors are fixed, but all are variable" (1962, p. 681). I would now add, all factors are perfectly mobile and divisible.

Against the backdrop of two models, I sketched the three economies of agriculture. These are, respectively, "the production of primary products from soil, the conversion of feedstuffs into livestock products, and the marketing of products from farm to retail" (1962, p. 679).

The models were useful for my study because they provided a reference point for examining the trend that had been so pervasive in agriculture throughout the century but especially since World War II, that of moving ever farther away from primitive agrarian toward an industrial form. This was the trend known as industrialization of agriculture. It was moving forward fast in 1962.

Industrialization impinged on the three economies of agriculture differently. By 1962 marketing had been almost fully transformed; it was then the most industrial of the three. The livestock and poultry sector was intermediate. However, it had moved fast toward managerial, if not locational, detachment from feedstuffs and it thereby became much more industrial than when it was a subordinate part of feed crop production on individual farms. Only crop farming still showed significant features of a primitive economy and remained partly in thralldom to forces of nature.

Moreover, the most industrialized economy was also the fastest growing. Marketing had been expanding faster, in terms of battery of services performed, than production of either livestock or crops. And between the latter two, livestock and poultry had been edging ahead of crops.

On the other hand, in 1962 the least industrial of the three economies was industrializing the most rapidly, as though it were racing to catch up. Crop production was in the throes of a technological revolution that was bringing many more industrial materials and techniques to it. "Production on U.S. farms has been shifting at fast pace to an industrial, capital-using, character" (1962, p. 685).

There followed in my article an enumeration of inferences to be drawn from industrializing all three economies and especially primary production. Among these were a reduced role for land; more inelastic farm-level demand for crop products as those products became farther detached from final consumption; the greater potential controlability of farm output, a control exercised by terms of access to industrial inputs; the better case that could be made than before for basing commodity support prices on cost of production; and the growing imperiousness of the marketing system over both primary (crop) and livestock production.

Time and Place Restraints; New Setting for Three Economies

Events since 1962 illustrate once again how quickly can trends reverse and predictions prove faulty. They remind that contemporary economic analyses are implicitly tentative, being confined within the boundaries of the data that give rise to them. This theme, often captioned as risk in extrapolation, is accounted for in terms ranging from the *ceteris paribus* caveat (some constants do not stay that way) to the cross product term in a squared equation (a dog multiplied ten times could not support its weight). A more scholarly reference is to laws of composition which, according to the logician Sherman Roy Krupp, "determine the range within which a particular basic relation will hold" (p. 47). The range is distinctly limited.

The events were the sudden increases in the price of a number of nonfarm inputs to agriculture that are crucial to its industrialization. They dated mainly in the 1970s. In the lead were tripled or quadrupled costs of petroleum and other fossil fuels. Various derived products also became more expensive. Equally important, though, was a resulting shift in psychology. A new sensitivity to the resource

base for agriculture came into view. Instances of fear for future food supplies bordered on panic; and they were matched, as usual, by some iconoclasm. Both have largely dissipated, being replaced by a near-consensus that industrial inputs, though not critically scarce, will not be as cheaply available in the future as in the past. Their prices may continue to increase relative to farm product prices, instead of lagging as in earlier decades.

(Between 1960 and 1976 both the consumer price index and wholesale price index fell short of doubling, but the wholesale price of fuels and power nearly tripled. Farmers' prices paid for tractors and "other self-propelled machinery" increased 140% just between 1965 (first year of data) and 1976.)

The developments, moreover, were unexpected, heightening their drama. In 1962 scarcely a murmur warned of any braking to continued industrialization. "There is as yet no sign of let-up in [trends] underway. Primary production continues to become more capital-using. Livestock enterprises still threaten to leave their traditional home. Marketing gains ever more size and dominance" (Breimyer, 1962, p. 690).

Evidence of Changed Trends in the Three Economies

Before evidence of post-1962 trends is considered, a reminder is in order. Seldom in historic evolution does a trend so about-face that the status quo ante is restored. More often, not only is the picture mixed but changes are small and subtle rather than graphic.

So it is with observations for the period since 1962. But there are enough positive indicators to suggest that a shift from steadily decreasing relative prices of nonfarm inputs to current and prospective increases has palpable effects.

Perhaps most meaningful is the altered public attitude toward food productivity, and toward food policy, that follows from awareness that industrial resources will not henceforth be so plentiful. Smaller crops in the 1970s and disappearance of reserve stocks of grain unquestionably gave the farm and food economy a rare conspicuousness. As of late 1977 a new surplus of wheat seemed to be building up. Whether it will dispel public attentiveness remains to be seen. But an entry will have been written in history's logbook: citizens become alert when they believe their food supply to be threatened.

Gross Productivity

Manifestly, a partly industrial agriculture is sensitive to productivity in the entire economy in a way that the older agrarian agriculture was not. On a common sense as well as theoretical basis higher cost energy has macro effects retarding growth. Rasche and Tatom allege that recognition of the effect of energy cost has come slowly because of the "usual practice of estimating the functional relationship between [aggregate] output and only labor and capital resources," which "implicitly assumes that changes in the stock and flow of energy resources are captured by the movements in the capital stock and need not be explicitly taken into account." They take energy explicitly into account as they enter it "as an integral part of the production function." When they do so, estimates of the potential output of the economy are reduced several percentage points (June 1977, p. 14 and ff.).

Relative Growth Rates of Agriculture's Economies

When we look at agriculture alone, we naturally find that although productivity slowed somewhat in the 1970s, it is virtually impossible to isolate energy-cost from climatic and other influences. Even so, a feature of trends since 1962 has been a different pattern of relationship between the three economies than prevailed before. The change could hold meaning.

Recapitulating: in 1962 the most industrial economy, marketing, had been growing the fastest and the least industrial, primary production, the slowest. Recounted then was that in 1948 the farmer's share of the retail value of all food had been 51%, but by 1961 it was down to 38% (Breimyer, 1962, p. 688).

In the mid-1970s the farmer's share climbed to above 40%. In 1976 it was 40%. Marketing had not continued its gain relative to the other two economies; if anything, it had slipped a bit.

More clearly to be seen, however, was a slowdown in the livestock economy. Over many previous decades livestock and poultry production had prospered. It outpaced crop production in volume and in contribution to farm cash receipts. Bolstered by strong de-

mand, in the later 1950s livestock and poultry sold were 55% of all cash receipts—56% if government payments be excluded.

During the 1970s feed grain-livestock relationships somersaulted. World demand for available feed supplies became strong, and devaluation of the dollar encouraged exports. Price ratios in feeding were squeezed. The volume index for livestock and poultry production in the United States in 1976 stood at only 117% of the 1960 base year. Crop production was 127% of the 1960 base. Even more impressive are data for the 1970s on livestock's share of farmers' cash receipts. At mid-decade livestock and poultry accounted for only 48% of all receipts—49% when government payments are omitted. Inferences must be drawn cautiously; relationships could reverse again. But there is at least a hint that primary products of agriculture have recovered some of the status they lost during prosperous and expansive postwar years.

Organizational Separation of Feed and Livestock

One earlier trend reported in 1962 seems definitely not to have stopped. It is the trend toward separating livestock and poultry enterprises from feed crop production.

Corn farmers in the Midwest are not going back to raising hogs or feeding cattle. They definitely are not buying laying hens or broiler chicks. New large-scale hog units pop up monthly.

Several factors account for corn farmers' disinterest. Among them is several years of good profits earned from grain alone, which spared them financial pressure to intensify. Also, some cattle and hog feeding is financed in part by tax shelter capital funds, and as so subsidized is a strong competitor to farmer feeding.

Even so, the situation could be over-read. Although large cattle feedlots continue to displace farmers' smaller ones, a number of them are custom operations—hotels for the animals of farmers and ranchers among the various owners.

Also, a slight counterpressure originates from new extension programs. The Cooperative Extension Service, embarrassed by its selective counselling of larger farmers, has inaugurated a special educational program for small farmers. Farmers on limited acreage are commonly advised to add livestock.

Disconnection Between Farmers and Consumers

Industrialization of agriculture tends to confine crop farming to producing primary products that are sold in raw form. It widens the difference in both form and value between those products and the foods that reach consumers. This feature of industrialization was described in 1962. It is doubtful that any major change has occurred since then. The marketing economy, organized for imperfect rather than perfect competition, has continued to emphasize merchandising rather than least-cost delivery of basic product. Growing popularity of restaurant and other group food service is of the same genre, although too much significance ought not be attached to it. Institutionalized food service as an alternate to home preparation is no longer just homecraft but can be regarded, with only slight overstatement, as miniature industry.

A few signs of opposite trends also can be found, though they may be little more than straws in the wind. Notable in the 1970s has been a halt to so much pre-preparation of foods sold at retail, once widely heralded. Resurgence of farmers' produce markets and even of pick-your-own fruit and vegetable farms, together with scattered interest in simple consumers' food cooperatives, are symbolic of agrarian rather than industrial food delivery. Quantities in such direct marketing are trivial but the portents may not be.

Production Control Policies

In 1962 it was pointed out that the then-current practice of relying on acreage controls to restrict the volume of farm production was an anachronism. If nonfarm materials constituted 62% of all inputs to agriculture and land was less than 15%, the estimates for that year, it seemed scarcely appropriate to use land alone as the factor of control. Not mentioned was the further point that land controls funnel program benefits almost exclusively to the land factor. Many economists have called attention to this consequence of land retirement. See Gaffney, for example.

In the mid-1970s, when tighter supplies of nonfarm inputs and bad weather shared blame for interrupted production trends, production was not restricted. On the contrary, maximum output was officially encouraged. Consistent with previous philosophy, it was to be attained

by planting more acres—"fence row to fence row" (a literary figure, as many fences had been removed).

Yet in an ironic twist, in other quarters during the 1970s, the nonfarm input of petroleum and other fossil fuel energy came to be recognized as an instrument of control. At the time of the oil import embargo and allocations, with further tightness threatened, the oil supply was seen as an instrument to hold farm production up.

If need for more production became at that time a rationale for asking to protect fossil fuel supplies to farming, the counterpart would be to turn niggardly at time of farm surplus. If the inflow of oil from abroad should be slowed when farm products are in oversupply, chances are that petitions for 100% allocation for farming would not be heeded.

So long as oil enters the United States as fast as supertankers can deliver it, the prospects are that "production control" will be confined to setting aside land. Such a policy was built into the 1977 farm law and applied immediately to wheat. It bids to prove no more effective than before.

A less contrived way to regulate farm production is to establish quantity marketing quotas. They allow the agrarian resource of land and the industrial one of nonfarm inputs to be balanced more rationally, and more effectively, than is possible when only acreage of land is controlled. Except for some types of tobacco and a few specialty crops, quotas have not been employed. Nor are they likely to be soon.

In looking at production control, however, we could easily overaggregate. Energy policy could intrude locally, apart from the national scene. An instance is energy for high-intensive forms of irrigation. Signs are that discrete decisions will be made about allocating energy and they will not be wholly concessionary to agricultural interests. Some pump irrigation fueled by natural gas may be the first casualty.

Focus on Land

If nonfarm inputs will not be so generously available in the future, farm inputs will climb a notch or two on the prestige scale. They will also attract more policy attention. Consistent with developments of the time, a new appreciation of the crucial role of farmland seemed to appear in the 1970s. Unlike production control, its context is long run.

Halting steps began in the 1970s toward protecting land for farming. Differential assessment schemes were one. If they promised little lasting benefit, their announced intent was no less noteworthy. In 1976 Secretary of Agriculture Earl Butz called for the first time for a farmland-preservation ingredient in USDA policies. His successor, Robert Bergland, echoed the theme.

Elasticity of Farm-level Demand

In 1962 it could be said with some confidence that farm-level demand for primary products, such as grains and cotton, had become highly inelastic.

If agriculture is now less industrialized, or if at least some of the thrust toward industrialization has eased, is that demand now less inelastic?

Neither statistical studies nor logical deduction can provide an answer. Statistical analysis will not do so because the time series for the new period is too short for reliable results. Logically, we could expect that if the marketing economy has reverted even slightly toward selling primary products instead of merchandising brand-named processed ones, farm-level demand would show just a little less inelasticity than before. We can doubt this has happened.

The snag in reaching a judgment is the nature of export demand, which has grown stronger since 1962. According to traditional theory, world demand for a nation's products is elastic because the world is so big and each nation's exports so small. The world is indeed big, but demand is fractionated and separated into national clusters, each of which has its own behavioral syndrome. Also, for some products the United States is not a small exporter. No resolution of the demand-elasticity issue seems possible. In today's trading world, the concept of aggregate elasticity of demand seems to be inappropriate.

The Economics of Value Determination

Economics is concerned not only with the physical wealth of nations but also with the determination of value. Perhaps the latter ranks first in importance. My 1962 article implicitly if not explicitly sketched a functional relationship between the value (price) of nonfarm inputs and of farm resources, principally

land. Heavier use in farming of cheap nonfarm inputs, I wrote, would lead to a "gradual subordination" of land values in agriculture (p. 691).

By parallel logic, the idea of basing commodity price supports on cost of production took on some credibility. "To the extent farm output now rests on variable nonfarm capital inputs, cost of production may at last achieve respectable status. At the least it is not as inapplicable as it once was" (p. 697).

It is questionable whether land prices ever were subordinated, gradually or otherwise; and in any case, they did not continue so. One complication is the mixed relationship between an input such as commercial fertilizer and land: it is partly complementary, partly substitutive (Breimyer, 1977, p. 22). Events of the mid-1970s nevertheless suggest that the perceived scarcity and higher price of inputs such as fertilizer, pesticides, and herbicides contributed to skyrocketing land prices. Although inflation-sped, tax-subsidized speculative demand also was involved, the higher current and prospective prices for industrial inputs to agriculture helped to send land prices upward. The national index of farmland prices more than doubled between 1972 and 1977 and some regions reported substantially faster escalation.

With regard to nonfarm inputs and cost of production, in the 1973 farm law the cost criterion was acknowledged, and in 1977 it attained "respectable status." Although the recognition may have come a little late, it is still germane. But as another instance of irony, it would have been a bit easier to base production costs on nonfarm inputs in the late 1950s and early 1960s. The price of land was less volatile then.

Building a production cost into a farm price support law is relatively easy so long as only the cost of purchased nonfarm inputs need be covered—nuisance problems of specification notwithstanding. To try to protect any substantial part of land prices is another matter. If land prices should continue to propel themselves upward, it will be increasingly difficult to exclude them from cost data for price support. Farmers' protests of inequity, not entirely baseless, will then override economists' objections based on the contrasting economics of land and nonfarm inputs.

Pure Ricardians could remind, though, that marginal land yields no rent and that to fail to include any rent in support prices discriminates against farmers of that land. Testimony the Missouri Farmers Association offered the U.S. Senate in connection with 1977 farm legislation was more introspective than that of some economists (Carpenter, p. 2).

Industrialization and Rental Return to Land

The primitive (agrarian) and industrial models for an economy have opposite welfare implications including those of income distribution. As set forth by Robinson and myself, the industrial model, though requiring highly sophisticated management, allows production to be subservient to consumer demand. Income-distribution, in Robinson's words, is free of "persistent differences between factors of production" (p. 6). As all products are tailored to consumer specification, returns are constant and there can be no consumer or producer surplus: no rent. Would there be quasi-rent? Possibly but if so it would be short term and limited to consumability of capital goods. As I noted, the fact that the industrial model is not fully achieved does not vitiate its significance (1962, p. 681).

It must be admitted that although the industrial model in pure form yields no differential returns to factors, partial monopoly and guild rules can replicate rent-like returns. Also, Galbraith asserts that in the contemporary industrial world consumer sovereignty is replaced to high degree by producer sovereignty. As with most models, coexistent reality does not conform at all closely; and an indiscriminate welfare-judgment transfer from the model to the "real world" is not warranted.

It is the primitive economy, not the industrial, that by its very nature yields differential returns. Higher return to super-marginal than marginal land, the unearned income known as rent, has always been disruptive. When agriculture is organized as composite entrepreneurial ("family farm") units, the distributional effect is minimized because rent becomes an indistinguishable supplement to income from the operator's labor and management. But contrariwise, the greater the rent, the stronger the pressure to change the organizational structure and stratify the roles for landholders and operators.

The trend toward industrialization of agriculture once bade to even out rents just a bit—although creating separate issues of who will hold the industrial (finance) capital of ag-

riculture and who will provide the technical management. If industrialization now lags to any appreciable degree, both current rent and its capitalization into capital gains will be of persistent significance. Contests will ensue to get and keep the right to receive both, and will become entwined in income and estate tax rules. In other words, we will see a repetition of episodes such as those of the mid-1970s. In 1972-76 real estate value in agriculture alone increased $233 billion, appreciably more than the $152 billion net income from farming operations including net rent paid to non-operator landlords (Breimyer, 1977, pp. 47–48). And the long-established income and estate taxes, as partial redistributors of income, ran into almost violent opposition for the upsetting reason that the capital-value inflation that gave rise to tax liability also created cash flow problems. Tax shelters were sought, and an aggressive Ag-Land Fund proposal of Continental Illinois National Bank was widely publicized (Matthews and Rhodes).

Whether the future brings an industrially-based high productivity in primary agriculture, dampening values in land and land rents, or whether the opposite occurs, will have a great deal to do with both income distribution and structural organization in agriculture.

The Economics of Raw Materials

We turn now to a new topic, the economics of extractive industries.

Joan Robinson considered only two models, the primitive and industrial. The latter in turn derived from the exciting revelation that there can be constant returns in the economy or even increasing ones, as described in the empty boxes trilogy. Thereupon optimism reigned as principles of economic development were formulated and espoused.

An industrial economy is a fabrication economy. It brings together and "works up" cruder materials. The industrial model itself contains no concern for the terms of availability of those materials. Implicitly they are regarded as costless except for the mechanics of extraction, itself incorporated in the industrial process. That is to say, in Robinson's industrial model there is no room for a reservation price on the crude oil or coal or metallic ore, no calculus of the anticipated price effect of progressive exhaustion of a stock material. Nor, in fact, is there any occasion for rent to the better oil fields and mines.

It is not coincidence that the beneficence of industrialization was given both scholarly and political expression during a period in Western history when raw materials were plentiful and the expectation was that new discoveries would be more yielding than the previous ones.

The empty boxes authors, nevertheless, did not entirely overlook the extractive economy. None of them, however, took note of the article on the subject published by the U.S. agricultural economist L. C. Gray in 1914. Gray recognized the "indistinguishable elements" in rent from "exhausted" and "inexhausted" properties, namely, "return for the coal used up and the return for the site value of that coal" (p. 468). He also pondered distinctions between royalty (depreciation fund) and rent (p. 484).

Clapham noted mineral extraction as a special case, perceptively and presciently. "Nature's response to the miner is notoriously reluctant," he wrote. Furthermore, "A time must come in the history of the planet, as a time comes in the history of every pit, when equal successive 'doses' of resources will yield small physical returns" (p. 121). But in keeping with the sanguinity of his generation Clapham pettifogged in terms that there were new lodes of coal in the Transvaal and the world was "fast becoming a single market for coal. . . . So far as our economist knows the work is not yet begun," he concluded (pp. 121–22).

We can read into Clapham's evasiveness the assumption that stock resources were neither to be given a reservation value nor allowed any sort of private monopoly. The returns box into which coal mining was to be placed would depend solely on productivity in extraction. As Clapham was optimistic about productivity, he seemed to swallow hard and put coal in the increasing returns category.

So it proved to be. So it was for a long time with coal, and with oil and metals too. There were, in fact, increasing returns in the extraction process. Cheap iron was used to drill for cheap oil which in turn powered excavation of more ore; and both iron and oil relieved the human back in mining coal. It was a nice symbiotic relationship.

During this comfortable interlude, few economists reconsidered the extractive phenomena. Hotelling took up the issue in 1931. Depression and war distracted; and only in the 1960s and 1970s, under institutional sponsors such as Resources for the Future, was the

subject opened up widely. In his Fellows address of 1977, Kelso recapitulated strains of thought about the extractive economy and remonstrated his profession for its lagging interest. He chose the contemporary language of spaceship earth as a closed system: "All of us . . . must incorporate in our analytical structure the conception of the closed spaceship earth, improvement in the well-being state rather than maximization of the throughput of the system. . . ." (p. 27).

Raw Materials and an Industrial Agriculture

The economics of extractive industries is relevant to our topic because, insofar as the trend toward industrialization of agriculture has slowed, the cause lies, as was stated above, not in inadequate technological processes but in higher cost of mineral raw materials, fossil fuel energy above all.

For the bulk of the nonfarm inputs that have contributed so much to the productivity of all three economies of agriculture are derived from extracted materials—the fossil fuels, mineral rock (phosphate and potash primarily), and metal ores. During the glory days of drawing on those resources they were available at a price that was almost perfectly elastic (i.e., the quantity agriculture chose to use had little perceptible effect on the supply price), and in real terms was constant or declining. Even the quotas on delivery of oil administered by the U.S. Department of the Interior and the Texas Railroad Commission were scarcely restrictive; and depletion allowances were intended to keep the crude flowing and prices comparatively low.

Now that those palmy conditions no longer hold and are even less likely to prevail in the future, what is the meaning for agriculture and particularly for the industrial part that has relied so heavily on abundance and cheapness in basic materials?

It is a new problem. Obviously, as mineral deposits become less accessible, by no stretch of the imagination is the returns box the increasing one nor is it even constant. It is decreasing. Moreover, in all likelihood deposits in some sources will be much less accessible than in others. The extractive model then displays much in common with the primitive model associated with agrarian agriculture. It particularly reintroduces the factor return of rent. At whatever high cost source a mineral price is established, all other sources will enjoy a superior return, which is rent.

Sharply different, however, from the primitive model of agriculture is the element of reservation price. Once progressive depletion of a resource is recognized, its price can have a reservation component. Superficially, attaching a reservation price resembles monopoly. Is it true monopoly? If so, it is monopoly without necessarily having monopolists! Herein we get the unique feature of economics of extractive industries.

Any holder of a stock resource, however small and powerless, who believes that the depletion process will result in a price uptrend exceeding the rate of interest on money will find it advantageous, if his liquidity situation permits, to hold instead of selling. This is a temporal-reservation function. Agricultural economists will recognize the parallel with a corn farmer's guessing whether the price outlook favors his holding or selling. The crucial difference is that more corn will be produced next year. No replacement oil will be forthcoming.

Separately from that, if the holder or coalition of holders is large enough to exert monopoly power and thereby make a future price rise more certain, the attraction to ration current output becomes greater. Thus, where reservation pricing is appropriate, the temptation to form organized oligopoly or monopoly is enhanced. (The implicit present- versus future-monopoly calculations of OPEC heads are interesting to simulate. Few if any data are available as clues.)

Without overstatement, the returns to a firm in an extractive industry can potentially be the sum of a nonmonopolized reservation price, a monopoly booster to it, and a bonus for any favorableness of location and accessibility.

The most dramatic current illustration is OPEC petroleum. Reportedly, for some Saudi Arabian oil, easily extracted and delivered, the reservation, monopoly, and rental components add to 80% or more of the cartelized delivery price. As of 1977 it was U.S. policy to compromise the price consequence by tiering the price of domestically produced oil. Thereby oil would be made available at the average of two marginal costs, the simplest case of average- rather than marginal-costing.

So it is that the economics of a steadily depleting raw material resource base has become an element in the economics of modern agriculture. It becomes that via the intermediate stage of economics of the industrial process. If the economics of the extractive sector has been neglected in the past, cir-

cumstances will force more attention in the future.

And as both practices and policy in agriculture respond to extant forces, irrespective of whether they are given intellectual expression, we can expect counteracting activities to make their appearance. Decision choices are inescapable between trying to protect agriculture's access to remaining supplies of nonfarm inputs of extractive origin and the opposite course of developing anew, in imaginative variants, the native (primary) resources of agriculture. Indeed, whenever a farmer plows under legumes or dries corn with sunlight or delivers fresh vegetables to a nearby village market, he counteracts by agrarian means the consequences of an oil supply that is not only running out but being reserved by its holders.

Resumé

In the foregoing pages a two-stage message has been presented. The first is a reconsideration of trends toward progressive industrialization of U.S. agriculture, a reconsideration prompted by a sudden increase during the 1970s in the relative price of nonfarm inputs. In 1962, when the meaning of industrialization was examined, agriculture was in the postwar industrialization surge. Effects differed among agriculture's three economies, as primary crop production, still the least industrial, was overshadowed by the livestock enterprises and by the third economy of marketing.

In the decade and a half since 1962, higher costs of nonfarm inputs have slowed the pace of industrialization. Some consequences have appeared. Marketing has not outrun the other two economies as it did before, and the livestock and poultry economy has felt some restraint. More clearly to be seen are an awakened public interest in farm and food affairs, a resurgence of the primary crop economy to prominence, and a newly expressed regard for farmland as an essential and irreplaceable resource. Whether the larger crop harvests of 1977 and reappearance of sizable stocks of grain will defuse some of the recent trends remains to be seen. A major reversal seems unlikely, for the reason that the higher cost of nonfarm inputs in the 1970s is ascribable to changes in the supply and price of raw materials that will persist.

The second stage of analysis is directed to the economics of extractive industries, a subject neglected for so many years when abundant raw materials were taken for granted. Models for primitive agrarian and industrial economies, useful for tracing the industrialization of agriculture and themselves derived from three classic articles on "empty economic boxes," are inapplicable to the extractive sector. The analysis sketched here is not definitive yet echoes ideas as old as those of Gray of 1914, and recognizes in the pricing of extractive products an implicit temporal-reservation price to which is added any monopolization element plus the rent some suppliers get by virtue of their advantaged location.

The principal inference to be drawn is that the economics of agriculture will henceforth comprise not only the economics of its unique resource of the land together with that of superimposed industrial processes, but also the economics of access to mineral raw materials that are constituents of industrial technology. The practice and politics of agriculture will divide two ways, between sheltering agriculture from the deleterious effects of more costly raw materials, and fostering the protection and development of those native resources of agriculture that sustained humankind before the first phosphate was mined or oil pumped, and that have never been superseded.

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Supply Shifts and the Size of Research Benefits

R. K. Lindner and F. G. Jarrett

This article claims to do three things. First, develop a formula for measuring size of research benefits which is generally applicable to all types of supply shift. Second, use this formula to assess the possible error involved in previous studies employing alternative equations. Third, initiate discussion on variables which might influence the type of supply shift. The article concludes that uncritical application of previously developed formulas without regard to the type of supply shift can result in substantial bias in estimates of research benefits. The implication is that calculation of rates of return on agricultural investment may also be severely biased.

Key words: consumers' and producers' surpluses, general formula, research benefits, supply shifts.

The first attempt by Griliches to measure the benefits of research found a very high rate of return on this type of investment, and recent reviews by Arndt and Ruttan, and by Evenson and Kislev reveal that most subsequent studies have also reported a high rate of return. These findings have often been used to support claims for increased funding of agricultural research.

Two basically different approaches to the measurement of research benefits have been used. The first can be described as the production function approach and involves estimating marginal productivity of research. The second approach employs the techniques of cost-benefit analysis and measures average productivity of research. A vital part of this approach is the estimation of the annual social surplus created by the downward shift in the long-run supply curve, which results from the adoption of research results in the form of process innovations. This paper concentrates exclusively on the latter approach to measuring research benefits.

The main contention of this paper is that all previous techniques used to measure gross annual research benefits (*GARB*) may produce biased results simply because insufficient attention has been paid to the manner in which the supply curve shifts in response to adoption of a process innovatioh by rural producers. Definition of the area to be measured as that below the demand curve and between the two long-run supply curves is not in contention. What is of concern are the procedures used to measure this area. The theoretical basis for using the long-run supply curve in measuring economic surplus is developed in Currie, Murphy, and Schmitz. "The literature on the long-run supply curve of a perfectly competitive industry is vast. . . . There is widespread agreement that it does represent the average costs of each firm in the industry. . . . [in] an industry with a fixed supply of land and with all other factors available at constant prices . . . the supply curve is then a long-run average cost curve including rent to land and a long-run marginal cost curve excluding rent to land" (p. 757). Our subsequent discussion on the nature of supply shifts is based on the effect of various types of innovation on the structure of average costs for firms in the industry.

Apart from establishing the simple but fundamental proposition about the importance of the type of supply shift, the paper seeks to make three other main contributions. The first of these involves development of a general formula for measuring the area of *GARB* which is independent of the nature of the supply shift, provided linear demand and supply curves can reasonably be assumed. The sec-

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ond is to use this formula to calculate the magnitude of error likely to be incurred by using equations developed in previous studies to calculate the level of *GARB*, and to provide the basis for some reassessment of the significance of selected past studies. The final contribution involves an attempt to initiate a discussion of the variables which will determine the type of supply shift. Specifically, an attempt is made to provide some limited a priori generalizations about the types of supply shift likely to be associated with various innovations.

Why the Type of Supply Shift Matters

To simplify the discussion, two principal types of supply shift will be distinguished. The first will be referred to as a divergent shift, and includes all cases where the absolute vertical distance between the supply curves increases as quantity supplied increases. The pivotal and proportional supply shifts illustrated in figures 1a and 1b, respectively, are two special cases of a divergent shift. A divergent shift implies that absolute reductions in average cost are greater for marginal firms than for inframarginal firms. A convergent shift is one where the absolute cost reduction at inframarginal levels of output is greater than at marginal levels of output, and this is illustrated in figure 1d. Obviously, the case of a parallel shift in the supply curve, figure 1c, separates these two main types of supply shift.

To measure *GARB*, some assumption about the nature of the supply shift must be made. However, to the best of our knowledge, past studies have made no attempt to justify or explain the particular assumptions made about the type of supply shift. In fact, in some studies the impression is given that the type of supply shift was determined by the specification of the mathematical form of the supply curve, which in turn appears to have been chosen simply for computational convenience. Such lack of concern about the nature of the supply shift would not matter if the measured level of *GARB* were insensitive to the type of supply shift. Duncan and Tisdell have already demonstrated that the nature of the supply shift is a key determinant of the distribution of benefits from research between producers and consumers. In this paper, it will be demonstrated that the assumption made about the type of supply shift also has an important

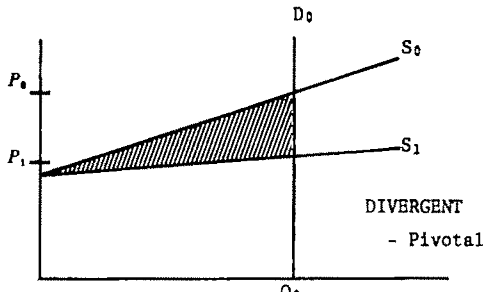

Figure 1a

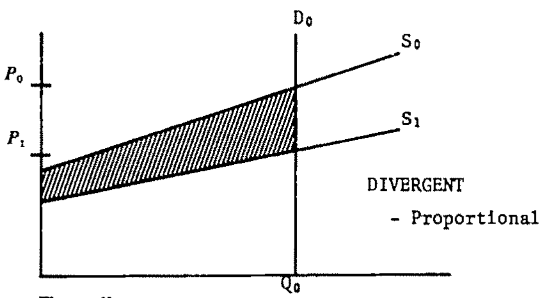

Figure 1b

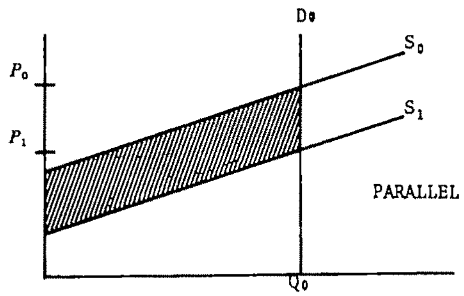

Figure 1c

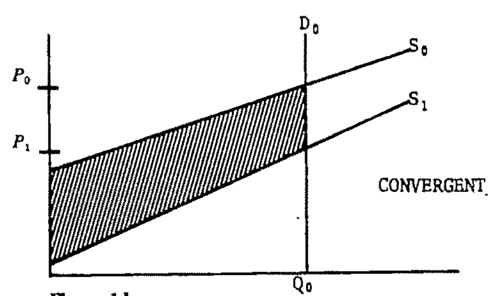

Figure 1d

influence on the measured level of total research benefits.

Most studies in the past have assumed a divergent shift of one form or another. For example, a pivotal shift was assumed in studies by Ayer and Schuh, and by Akino and Hayami. On the other hand, both Griliches and Peterson assumed a proportional shift in the supply curve, although, in Griliches' case, the supply shift is also parallel because he assumed a perfectly elastic supply curve. Although the authors know of no study which has assumed a convergent shift, there seems to be no reason, in principle, why such a shift should not occur.

The importance of the nature of the supply shift can be illustrated quite simply by considering the cases depicted in figure 1, where demand for the product is perfectly inelastic. Here the quantity of output will be unchanged at Q_0, and the effect of adoption of the innovation in each case will be to cause product price to fall from P_0 to P_1. The effect of different types of supply shift on the area measuring *GARB* can be seen easily from these diagrams. Clearly a pivotal shift generates the smallest level of *GARB*. As the shift becomes less divergent, and more convergent, the size of *GARB* increases. In particular, note that the size of *GARB* for a parallel shift is exactly twice that for a pivotal shift in this special case. Where demand is not perfectly inelastic, the situation is somewhat more complicated, but it will be shown below that the same general picture emerges.

The most important implication is that all previous equations used to measure *GARB* lack generality, as in all cases the derivation was based on the assumption of a particular type of supply shift. This deficiency is remedied in the next section.

Derivation of an Alternative Formula

Both Griliches and Peterson measured the benefits from adoption of an innovation by asking, what would have been the losses if this innovation were to disappear? We suggest that it is more helpful in evaluating the impact of agricultural production research to take the direct approach of measuring the gains from research relative to the pre-innovation market equilibrium, rather than the indirect one of asking what would be the losses if the innovation disappeared. Research managers know the current supply situation when making decisions about the quantum of resources to be allocated to agricultural research, and have to make estimates of the impact of the research on future supply conditions. That is, they need to estimate *ex ante* what the social benefits of research and their distribution are likely to be.

To simplify the presentation, we assume as an approximation linear supply and demand functions, and once again, S_0 and D_0 in figure 2 denote the initial supply and demand functions without the innovation. Adoption of the innovation results in a downward shift in supply to S_1. Treating the movement of the supply function as a vertical, rather than a horizontal, shift—the latter being used in the studies by Peterson and Akino and Hayami—emphasizes the cost reducing nature of innovations, and facilitates the way in which research scientists can understand the effect of their research on the supply of agricultural output.

In figure 2, *GARB* is measured by the rectilinear area $A_1M_1M_0A_0$ which, given the linearity assumptions made, can be decomposed into the areas of a series of triangles. In general, this area can be measured by the rule of cross multiplication (see Durrant and Kingston) which relies on the coordinates of the points A_1, M_1, M_0, A_0, A_1 expressed in an anticlockwise direction. The coordinates are O, A_1; Q_1, P_1; Q_0, P_0; O, A_0; and O, A_1 respectively. The area $A_1M_1M_0A_0$ is given by

$$(1)\quad \tfrac{1}{2}[O \times P_1 + P_0 \times Q_1 + Q_0 \times A_0 + O \times A_1 - O \times A_0 - O \times P_0 - P_1 \times Q_0 - Q_1 \times A_1]$$

which equals

$$(2)\quad \text{Total benefit} = \tfrac{1}{2}[P_0Q_1 - P_1Q_0 + Q_0A_0 - Q_1A_1]$$

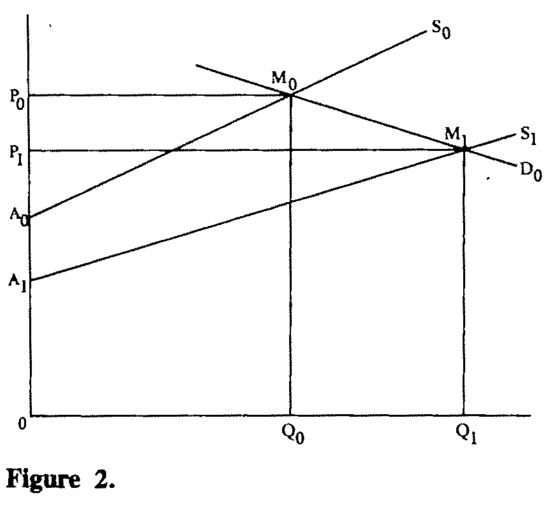

Figure 2.

The same procedure can be used to derive the following equation (3) for calculating the change in the size of consumer surplus, represented in figure 2 by the area $P_0M_0M_1P_1$.

(3) Consumer benefit
$$= \tfrac{1}{2}[P_0Q_1 - P_1Q_0 + P_0Q_0 - P_1Q_1]$$

If equation (3) is subtracted from equation (2), a measure of producer benefit is obtained. This is

(4) Producer benefit
$$= \tfrac{1}{2}[Q_0A_0 - Q_1A_1 - P_0Q_0 + P_1Q_1]$$

Within the assumptions made, equations (2), (3), and (4) are general results,[1] the application of which requires a knowledge of the original equilibrium price and quantity P_0, Q_0; the new equilibrium price and quantity P_1, Q_1; and values for A_0 and A_1.

Where research results have already been incorporated into production processes and an *ex post* measure of research benefits is to be calculated, data on P_1 and Q_1, i.e., current equilibrium price and quantity, can be obtained. However, the variables P_0, Q_0, A_0, and A_1 have to be estimated indirectly. Additional difficulties arise in applying the formulas *ex ante* as none of the variables can be observed directly. This is because P_0, Q_0 are sensitive to other unknown influences besides the adoption or nonadoption of the innovation. However, provided that demand and supply conditions are relatively stable, reasonable estimates of P_0 and Q_0 can be obtained from current levels of industry price and output. P_1 and Q_1 can be estimated using equations (5) and (6), adapted from those used by Pinstrup-Andersen, Ruiz de Londoño, and Hoover.

$$(5) \qquad P_1 = P_0\left(1 + \frac{k\epsilon}{\epsilon + n}\right)$$

and

$$(6) \qquad Q_1 = Q_0\left(1 - \frac{k\epsilon n}{\epsilon + n}\right).$$

[1] Griliches' measure of the loss associated with the disappearance of the innovation and derived by assuming a perfectly elastic supply curve, is $kP_1Q_1[1 - \tfrac{1}{2}kn]$, where k is the proportionate shift in the supply function given by $k = \dfrac{P_0 - P_1}{P_1}$, and n is the absolute value of the elasticity of demand. Evaluating this elasticity at P_1Q_1 gives

$$n = \frac{\Delta Q}{\Delta P} \cdot \frac{P_1}{Q_1} = \frac{Q_1 - Q_0}{P_1 - P_0} \cdot \frac{P_1}{Q_1}$$

If we substitute for k and n in Griliches' measure, then equation (3) is obtained. Note that in Griliches' special case $A_0 = P_0$ and $A_1 = P_1$, so equation (3) is also the same as equation (2).

In these equations, k is the proportionate reduction in average costs of production, measured at Q_0, from adopting the new technology, and ϵ and n are the price elasticity of supply and demand respectively. In a competitive industry k is equal to the absolute cost reduction, at Q_0, divided by P_0. Estimates of cost reduction can be made using the methods pioneered by Griliches and Peterson for *ex post* calculations, but "guesstimates" would have to be made in any *ex ante* evaluation of research proposals. The values of ϵ and n in the vicinity of P_0, Q_0 and P_1, Q_1 can be estimated by well-known econometric techniques, and in many cases are available from other studies. However, some caution should be exercised in using previous estimates of ϵ, since adoption of the innovations may alter ϵ in the vicinity of P_1, Q_1.

The problems of estimating A_1 in the case of *ex post* studies, or A_0 for *ex ante* studies, are less tractable. In general, we do not believe that econometrically estimated supply curves provide reliable estimates of the intercept term A because the available observations on P and Q used to calculate supply parameters are typically far removed from the point where the supply curve intercepts the vertical axis. Actual estimates of supply curves frequently involve, or imply, negative intercept terms. An abnormality such as this need not matter if the estimated supply curve is only to be used to project prices and/or quantities in the vicinity of the original data set, but in our case it is clearly illogical as it implies that producers are prepared to supply positive quantities at zero price in the long run.

One possible method of estimating A would be to ask industry experts the following question: *ceteris paribus,* to what level would prices have to fall for industry output to fall to zero in the long run? Obviously, a subjective procedure of this type is likely to provide widely differing estimates depending on the particular experts consulted. An alternative would be to use the range of average costs found in economies of size studies as an approximate guide to the value of A in relation to P. This would, of course, implicitly assume that producers with high average costs are marginal producers, and that factor prices do not change as industry output changes. The approximate nature of both of these approaches is mitigated by the fact, to be demonstrated below, that the estimated level of research benefit is relatively insensitive to the

value of A used. Estimated research benefits are, however, much more sensitive to the nature of the shift in the supply curve induced by adoption of the innovation. If a proportionate shift k is postulated, then

$$k = \frac{A_0 - A_1}{A_0},$$

so $A_1 = A_0(1 - k)$. Alternatively, a parallel shift implies $A_1 = A_0 - R$, where R is the absolute reduction in average costs for all firms, while $A_1 = A_0$ is the case of a pivotal shift.

Sensitivity of *GARB* to Incorrect Assumptions

The importance of the assumption about the nature of the shift in the supply curve can now be demonstrated quantitatively. Two types of divergent shift—proportional and pivotal—plus a convergent shift are compared in table 1 with a parallel shift, which is used as the numeraire.

The following computational procedure was used to produce these results. Given unitary values of P_1 and Q_1, and an arbitrarily chosen, but constant, proportionate reduction k in average costs at Q_0, equations (5) and (6) were used to calculate values for P_0 and Q_0. Various assumptions were made about local supply and demand elasticities in the vicinity of P_0, Q_0, and P_1, Q_1; and these are set out in columns 1 and 2 of table 1. The values of A_0 and A_1 required to utilize equation (2) were derived using the equations set out at the base of table 1 for each of the different types of supply shift, and for two arbitrary assumptions about the value of A_1 as a proportion of P_1, shown in column 3. These two values cover a wide range of possible locations of A_1. A value of 0.2 in column 3 implies A_1 is close to the origin while a value of 0.8 implies A_1 is close to P_1. Column 4 shows the implied arc elasticity of supply over the interval A_1P_1.[2]

Columns 5 through 8 of table 1 show the values of *GARB* calculated using equation (2). For each set of assumptions about supply and demand elasticities, the values are expressed as a proportion of the value of *GARB* for a

[2] Expressed in terms of average prices and quantities, this elasticity is

$$\frac{Q_1 - 0}{P_1 - A_1} \cdot \left(\frac{P_1 + A_1}{2}\right) \Big/ \left(\frac{Q_1 + 0}{2}\right), \text{ which equals } \frac{P_1 + A_1}{P_1 - A_1}.$$

If A_1 is expressed as a proportion of P_1, the implied arc elasticity can be calculated. For example, if $A_1 = 0.2P_1$ then the implied arc elasticity is $\frac{P_1 + 0.2P_1}{P_1 - 0.2P_1}$ which equals 1.5.

Table 1. Sensitivity of *GARB* to Assumptions About the Nature of the Supply Shift

Local Elasticity Conditions: Demand n	Local Elasticity Conditions: Supply ϵ	Intercept Term A_1/P_1	Arc Elasticity of Supply	Types of Supply Shift (Relative Benefits): Pivotal[a]	Proportional[b]	Parallel[c]	Convergent[d]
0.5	0.2	0.2	1.5	0.29	0.43	1.0	1.71
		0.8	9.0	0.24	0.85	1.0	1.76
	5.0	0.2	1.5	0.57	0.66	1.0	1.43
		0.8	9.0	0.52	0.90	1.0	1.49
2.0	0.2	0.2	1.5	0.19	0.36	1.0	1.81
		0.8	9.0	0.12	0.82	1.0	1.89
	5.0	0.2	1.5	0.70	0.76	1.0	1.31
		0.8	9.0	0.55	0.91	1.0	1.45

[a] $A_0 = A_1$.
[b] $A_0 = A_1(1 + k)$.
[c] $A_0 = A_1 + kP_1$.
[d] $A_0 = A_1 + 2kP_1$.

parallel supply shift. For example, the pivotal shift in the first row has benefits which are only 29% of those consequent on a parallel shift, and the benefits from a proportional shift are 43% of those from a parallel shift.

Inspection of the remaining rows in table 1 leads to the inescapable conclusion that the measured level of *GARB* is highly sensitive to the nature of the supply shift. This sensitivity is most pronounced when supply is locally inelastic, but even when local supply is highly elastic, making an incorrect assumption about the type of shift of the supply curve still results in a substantial measurement error. The only exception is the case where the supply curve is highly elastic over the interval back to the vertical axis, in which case the measured level of research benefit is much the same for both a proportional and parallel shift. This result is not surprising as in the limiting case where supply is perfectly elastic, a proportional shift will also be a parallel shift.

It is also important to test the sensitivity of measured research benefits to various assumptions about the value of the intercept term, A_1. This is done in table 2, where each row compares the measured level of research benefit when A_1 is 0.2, 0.5, and 0.8 of P_1. In this case, the measured area when A_1 is 0.5 P_1 is taken as the numeraire. Different rows again represent different assumptions about local demand and supply conditions, as well as a range of assumptions about the type of shift of the supply curve.

Table 2 reveals that, for a given type of shift, sensitivity to variations in the assumption about A_1 is generally low. The exceptions to this lack of sensitivity are both cases of a proportional shift when supply is locally inelastic, both cases of a pivotal shift for a locally elastic demand, and the case of a parallel shift where both demand and supply are locally elastic. However, even in these cases the measurement error involved in assuming that A_1 is 0.5 of P_1, when in fact it could be either up to 0.8, or down to 0.2 of P_1, never exceeds 35%. While values of A_1 outside of the range covered by table 2 cannot be ruled out, they would appear unlikely on a priori grounds.

A Comparison of Alternative Equations

In a recent entertaining note, Scobie highlighted the differences in estimated research benefits obtained by applying equations from previous studies. However, his paper only drew attention to the possibility (probability?) of biased results, but did not indicate the likely sign or degree of bias from using any given formula. In this section, equation (2) is used to calculate the magnitude of bias likely to result from using the two very well-known formulas derived by Griliches and by Peterson.

Table 2. Sensitivity of *GARB* to Assumptions About the Intercept Term

Local Elasticity Conditions		Intercept Term	Arc Elasticity of Supply	Types of Supply Shift			
Demand n	Supply ϵ	A_1/P_1		Pivotal	Proportional	Parallel	Convergent
				Relative Benefits			
0.5	0.2	0.2	1.5	1.12	0.70	1.03	1.02
		0.5	3.0	1.0	1.0	1.0	1.0
		0.8	9.0	0.88	1.30	0.97	0.98
	5.0	0.2	1.5	1.12	0.91	1.07	1.04
		0.5	3.0	1.0	1.0	1.0	1.0
		0.8	9.0	0.88	1.09	0.93	0.95
2.0	0.2	0.2	1.5	1.30	0.64	1.05	1.03
		0.5	3.0	1.0	1.0	1.0	1.0
		0.8	9.0	0.70	1.35	0.95	0.97
	5.0	0.2	1.5	1.30	1.10	1.19	1.14
		0.5	3.0	1.0	1.0	1.0	1.0
		0.8	9.0	0.70	0.90	0.81	0.86

Griliches derived two formulas in his path-breaking article on hybrid corn by making the simplifying assumptions that the supply curve was either perfectly elastic, or perfectly inelastic. He justified this approach by claiming that these "two estimates bracket estimates implied by assuming other intermediate supply elasticities" (p. 422). To evaluate this claim, annual research benefits were calculated using both equation (2) and the formula which Griliches claimed would provide a lower bound estimate of *GARB*, i.e.,

$$(7) \qquad kP_1Q_1(1 - \tfrac{1}{2}kn).$$

Table 3 sets out the percentage overestimation of *GARB* that would result from using equation (7) when supply was not in fact perfectly elastic. All values in this table are calculated for a 13% shift in the supply curve at Q_1, and for an absolute elasticity of demand equal to one-half, which were the parameter values assumed by Griliches in his study.

Nerlove's estimate of 0.18 for the long-run elasticity of corn supply was used by Griliches, rounded to 0.2 in his hybrid corn study. If this value is accepted, then Griliches' estimate of *GARB* of $341 million after full adoption of hybrid corn, overestimates the true value by somewhere between 76% and 225%. Nerlove expressed some qualifications about this apparently low long-run supply elasticity for corn. The comparable estimates for wheat and cotton were 0.93 and 0.67 respectively. However, the maximum value for the supply elasticity for corn obtained by Nerlove was only 0.35. Even if the estimate is raised to one, the overestimation is between 29% and 72%. In all cases, the overestimation falls as supply becomes more elastic—a result to be expected as Griliches' approach assumed a perfectly elastic supply.

However, because research costs to develop hybrid corn and maintain its productivity need to be subtracted from *GARB* to derive net annual research benefits, overestimation of *GARB* will lead to an even greater overestimation of net benefits and the rate of return. After allowing for such research costs, it was calculated that Griliches apparently overestimated the rate of return to hybrid corn research by at least 50% to 100% if a corn supply elasticity of unity is assumed, and by a substantially larger margin if long-run corn supply is assumed inelastic.

Table 3. Overestimation of *GARB* by Applying Griliches' Formula

Intercept Term	Arc Elasticity of Supply	Local Elasticity Supply (ϵ) 0.2	1.0	5.0
			%	
0.2	1.5	225	72	32
0.5	3.0	128	47	20
0.8	9.0	76	29	10

Similar calculations were carried out to gauge the extent by which a formula suggested by Peterson, equation (8), overestimates *GARB*:[3]

$$(8) \quad KQ_1P_1 + \tfrac{1}{2}K^2P_1Q_1/n - \tfrac{1}{2}Q_0K^2P_1\left[\frac{P_1}{P_0}\right]\left[\frac{\epsilon n}{n+\epsilon}\right]\left[\frac{n-1}{n}\right]^2.$$

Equation (8) is based on the assumption that the shift in the supply curve would be proportional. The equation was developed to assess the benefits of U.S. research on layers, broilers, and turkeys. Table 4 shows the calculated percentage overestimation for a range of parameter values.

The two values of demand elasticity assumed in the table span a range from an inelastic to an elastic demand curve and also approximate the range used by Peterson, viz., 0.34 to 1.61. Because the results are highly sensitive to the assumption about local elasticity of supply, calculations were also made for a wide range of values. Johnson suggested a value of between 2.6 and 4.2 for the elasticity of supply of livestock other than beef and dairy. For a supply elasticity of 3, Peterson's suggested formula clearly overestimates research benefits substantially, and perhaps by as much as 570% if the supply shift is proportional and demand inelastic. Although the bias from using equation (8) will be less if there is a parallel shift of the supply curve and demand is more elastic, it would seem likely that Peterson overestimated *GARB* from the adoption of new technology in the United States poultry industry by in excess of 150%. Overestimation of net benefits, and the rate of return, will be even larger for the same reasons already discussed in regard to Griliches' study. Only if local supply elasticity is about one

[3] In this formula K is defined as the proportionate horizontal shift in the supply curve, and can be converted to the proportionate vertical supply shift by the equation $K = k\epsilon$. Note also that n is the actual, not absolute, demand elasticity. All the other variables are as previously defined, although ϵ is not restricted to the local elasticity of supply.

Table 4. Overestimation of *GARB* by Applying Peterson's Formula

Local Elasticity Conditions: Demand n	Supply ϵ	Intercept Term A_1/P_1	Arc Elasticity of Supply	Types of Supply Shift: Proportional (%)	Parallel (%)
0.5	1.0	0.2	1.5	98	18
		0.5	3.0	69	24
		0.8	9.0	48	31
	3.0	0.2	1.5	470	269
		0.5	3.0	413	293
		0.8	9.0	366	319
	5.0	0.2	1.5	944	589
		0.5	3.0	850	634
		0.8	9.0	770	686
2.0	1.0	0.2	1.5	95	15
		0.5	3.0	82	29
		0.8	9.0	71	48
	3.0	0.2	1.5	265	162
		0.5	3.0	289	209
		0.8	9.0	316	275
	5.0	0.2	1.5	433	303
		0.5	3.0	486	380
		0.8	9.0	552	493

would the margin of error be of about the same order as for hybrid corn. Whatever the actual bias in Griliches' and Peterson's results, application of their equations can clearly lead to extremely large errors under certain conditions.

Further calculations along the same lines using equations from other studies have not been made in the interests of brevity, but a general lack of attention to the nature of the supply shift in the literature indicates that such an exercise would produce similar results to those presented above. However, one specification developed by Akino and Hayami deserves comment. The actual supply function assumed was a constant elasticity function of the form $q = Gp^{\gamma}$ which passes through the origin. A horizontal shift in the supply function is achieved by changing the value of G. This is clearly a case of a pivotal shift, and will underestimate *GARB* if the actual supply shift takes almost any other form. This assumption also predetermines their conclusions about the distributive effects of rice breeding research in Japanese agriculture, since Duncan and Tisdell have shown that producers' returns from research will be negative when research leads to a divergent supply shift, and when demand is inelastic.

The Nature of the Supply Shift

The emphasis so far has been on demonstrating the importance of the nature of the supply shift for the measured level of *GARB*. The discussion now focuses on the difficulty of predicting the nature of this shift. At the outset, it is essential to recognize the impossibility of making unqualified a priori generalizations about the nature of the shift in the supply curve. One important reason is that many agricultural innovations are location specific. For innovations which are specific to locations associated with the left-hand end of the supply curve, the absolute level of cost reduction is greater for inframarginal units of output than for marginal units of output, and the supply shift is of the convergent type. The opposite case of a divergent shift results from innovations which are specific to marginal areas of production, but less well defined shifts can result from other types of location specific innovations.

Some models of induced innovation such as that of de Janvry suggest that the majority of innovations are likely to be specific to areas owned and/or controlled by social elites. Furthermore, it is argued that even if these areas were originally marginal, over time they would

become inframarginal as a result of influence over research programs by the elite group, so that most agricultural innovations would produce a convergent supply shift. The problem of generalizing about the nature of the shift is further confounded by the entry and exit of firms from the industry as product price alters. If the entry or exit firms have markedly different cost structures than the existing or remaining firms, respectively, the supply curves may shift in a variety of directions. Unfortunately, little empirical evidence exists on these questions for most countries, and until further evidence on the nature of the shift becomes available, we are not prepared to draw firm conclusions about the relative likelihood of divergent versus convergent supply shifts.

In the case of hybrid corn, Griliches found that yield increased by the same percentage for all producers irrespective of the yield they were obtaining from open-pollinated corn. The relatively "low average cost" of inframarginal producers who are located towards the "bottom end," i.e., near the vertical axis, of the supply curve is thus likely to reflect higher yields per acre relative to the comparatively "high average cost" of marginal producers located at the "top end" of the supply curve. If total costs of both groups of producers are relatively unaffected by the substitution of hybrid seed for the previous seed varieties, then it follows that the cost structures for all producers are proportionately reduced, and the corresponding shift in the supply function will also be proportionate.

Hybrid corn is a biological innovation, but not all biological innovations need result in a proportionate shift in the supply function. For instance, the biological fixation of nitrogen through rhizobium does not greatly affect yields on soils with an already high nitrogen status, but often has a dramatic impact on low nutrient soils. If low cost producers are on the former group of soils, then the shift in the supply function consequent on this sort of innovation is likely to be highly divergent, if not approximately pivotal.

More generally, it seems that biological innovations are more likely to result in a divergent shift in the supply function rather than a convergent shift, provided, of course, that the innovation is diffused evenly. To understand why, note that a parallel supply shift implies the same absolute reduction in average costs for both low cost and high cost producers. In other words, for a parallel shift to occur, the innovation must lower per unit production costs by a substantially greater percentage for low cost producers than for their high cost counterparts. Where the cost of the innovation is the same to all producers, this condition requires that the percentage increase in yield for inframarginal (high yield) producers will be greater than for marginal (low yield) producers.

Biological disease control, as well as chemical innovations such as herbicides and insecticides, are also likely to result in a divergent shift in the supply function for similar reasons. An Australian example is the biological control of skeleton weed through a type of stem rust which is costless to individual producers. It thus lowers the cost structure of those (high cost?) producers whose farms had a high infestation of weed much more than for those (low cost?) farms with a low incidence of weed. Improved fertilizer technology through granulation and more precise positioning of the mixture may advantage both low yield (high cost), and high yield (low cost) producers equally, and the resulting divergent shift in the supply function may even be proportionate. On the other hand, fertilizer innovations in the form of added trace elements may well approximate a pivotal shift, since they will have negligible impact on high nutrient status soils which are likely to correspond to inframarginal producers, but will dramatically improve productivity, and hence lower average costs, for marginal, and even extramarginal, levels of output.

We have so far assumed in the main that the innovation is adopted equally by all producers. In practice, there is often substantial variation in the adoption of innovations by different classes of farmers for reasons other than the fact mentioned above that many agricultural innovations are location specific. Such differences in adoption rates and levels may depend on whether farms in the agricultural industry affected are diversified or specialized, and might also be related to farm size and/or managerial ability. Differential rates and levels of adoption of certain innovations only have important consequences for the nature of the shift in the supply curve if different classes of producers tend to be associated with production from particular parts of the supply curve. For example, if large scale producers tend to be low-cost producers, and vice versa,

then an innovation whose benefits are scale dependent results in greater adoption by inframarginal producers relative to marginal producers, and generates a convergent supply shift.

In contrast to biological and chemical innovations, mechanical and organizational innovations seem to us as likely to be scale dependent and result in a convergent shift in the supply curve. In the case of most mechanical innovations, there is a self evident bias in the direction of larger farmers. Economies of size studies suggest that these larger farms are also typically low-cost units, so the shift in the supply curve is likely to be convergent.

Organizational innovations are more difficult to categorize since they involve a change in the way things are done. However, it seems intuitively plausible that field consolidation, farm rotation systems, the use of decision-making aids such as linear programming, and similar changes are related to managerial skills. If low cost producers correspond to skilled managers, then they are located at the bottom end of the supply function. To the extent that the benefits of organizational innovations are positively correlated with managerial ability, the reduction in average costs is greater for such farmers relative to their high cost counterparts at the top end of the supply function, and the shift in the supply function is thus convergent. Alternatively, it could be argued that there is often a stronger incentive for managers of larger farms to adopt organizational innovations, since benefits are directly related to scale of operations, while costs of the organizational change are independent of scale. Again, a convergent supply shift is the outcome.

To the extent that it is possible to generalize, we conclude that *ceteris paribus* biological and chemical innovations are more likely to generate a divergent supply shift, but that the opposite effect will be generated by mechanical or organizational innovations. For any individual innovation, however, any a priori generalization needs to be taken with several pinches of proverbial salt, since our attempts to generalize have convinced us above all else of the great difficulty of doing so. This conclusion, together with the work of Duncan and Tisdell, mitigates the likelihood of any general tendency for the benefits of innovations to be captured mainly by either producers or domestic consumers; except, of course, for export oriented industries where demand is highly elastic. Furthermore, this result also applies to the conventional distinction between public and private rural research, given that biological and organizational research is predominantly public, and that mechanical and chemical research is largely private.

Conclusions

This paper demonstrates that the total level of annual social benefits from adoption of an innovation is influenced by the nature of the shift of the supply curve. To estimate aggregate research benefits, it is therefore necessary to estimate the effect of adoption of the innovation on the average cost of inframarginal production in addition to its effect on equilibrium price and quantity of industry output. Where the simplifying assumption of linearity can be made, we have presented a general formula for measuring such benefits. We contrasted results from this formula with other attempts at measuring research benefits, of which the studies by Griliches and Peterson have been taken as representative.

Griliches' assumption of a perfectly elastic supply seems difficult to maintain a priori. Our empirical results suggest that if this restrictive assumption is relaxed, as it was by Griliches himself in his own work on hybrid corn, then the application of his formula will, in general, lead to overestimation of research benefits and the rate of returns to research. Peterson's suggested formula which gives explicit recognition to the role of both supply and demand elasticities may also lead to substantial overestimation. In both cases, the returns to research are *ex post* but we suggest that our procedure based on the general result in equation (2) allows *ex ante* evaluation of research benefits and, as such, would assist in the allocation of resources to agricultural research. Our proposed alternative of estimating A_0 and A_1 directly is of course no simple task, and simplifying assumptions may well be necessary. By carrying out a simple sensitivity analysis our suggested procedure seemed fairly robust even when the only basis for estimation was to assume that A_1 was equal to .5 P_1 for the types of supply shift considered.

Finally, we draw attention to the complexities of specifying, a priori, the nature of

the supply shift and make some preliminary suggestions of those factors which might lead to particular types of supply shifts.

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Japanese Agricultural Distortions and Their Welfare Value

Malcolm D. Bale and Bruce L. Greenshields

Using a Corden/Johnson model the welfare costs of current and future Japanese agricultural trade and production policies are evaluated for the eight major cereal and livestock commodities produced and imported in Japan. It is estimated that the net social loss in consumption and production of 1975/76 import and production distortions for the eight commodities is $276 million and $111 million respectively. If the 1985/86 Japanese farm production goals are met the net social loss in production will rise dramatically to $7.6 billion. The combined production and consumption net social losses of the 1985/86 plan are equivalent to 2% of Japan's gross national product.

Key words: protectionism, trade distortions, trade policy, welfare.

The proposition that free trade is, from an economic point of view, more beneficial than protection is one of the most fundamental and widely accepted propositions in economic theory. The proposition rests on two basic premises—the static argument that trade barriers distort the optimal allocation of national and world resources and so reduce output, and the dynamic argument that economic freedom stimulates competition thus ensuring an environment beneficial to economic growth. Yet despite repeated advocacy of freer trade by economists and others, many international trade restrictions still exist.

In order to further document the case for free trade, several studies have sought to evaluate the cost of trade distortions. Recently the measurement of these effects on the welfare of society have been developed by a number of theoretical works (Bhagwati, Johnson, Magee 1972) and some empirical applications (Balassa, Basevi, de Melo, Magee 1973). Government intervention in the market mechanism drives a wedge between domestic prices and domestic opportunity costs. Abstracting from a dynamic world, the first-order conditions for a welfare maximum require that the marginal rate of transformation between any pair of commodities in domestic production equal the foreign marginal rate of transformation and the marginal rate of substitution in consumption. Theoretical developments have explored the efficiency implications of a collapse of these equivalences. Most empirical attempts at measuring the costs of trade distortions are based upon the more pragmatic Marshallian concept of economic surplus, where the welfare cost of protection is derived in terms of domestic elasticities of supply and demand, frequently with the assumption of a perfectly elastic foreign-offer curve. (Currie, Martin, and Schmitz have reviewed the concept of economic surplus.) This empirical exercise follows that same tradition using a Corden/Johnson type model to evaluate the net social cost of current and future Japanese agricultural trade and production policies.

Agriculture in Japan

While Japan has a modern and highly developed agricultural industry, it nonetheless is the world's largest net importer of agricultural products. The reader is referred to Hayami, Akino, Shintani, and Yamada for a comprehensive treatment of Japanese agriculture. Its agricultural production and marketing system may be characterized by government intervention at almost every facet. Producer support prices, input subsidies, government monopoly middleman activities, a plethora of

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agricultural trade restrictions, and imposition of the so-called "administrative guidance" are common examples. As a result, producer and consumer prices for agricultural products are considerably above world levels, sometimes as much as double those prevailing in the United States (Sanderson). An exception is wheat prices over the 1974–76 period. While world wheat prices increased dramatically, the Japanese government maintained consumer prices of wheat at their earlier levels for other policy reasons.

Despite the welfare loss that such policies generate, the Japanese government is undertaking an ambitious Coordinated National Food Supply Program in an attempt to increase domestic food production over the next decade.[1] The reason for this change appears to be based on official concern for the vulnerability of Japan's economy to commodity price fluctuations, given its high degree of dependence on foreign food sources. Table 1 presents the current and planned disposition of selected major agricultural products in Japan. The table reveals that production of livestock and all major crops except rice are to be expanded. Expansion will not be a simple task as Japan is a small, densely populated country with little arable land. Such agricultural expansion is to be achieved by higher trade barriers and larger production incentives. This policy clearly will result in larger welfare costs for Japan. In the following sections we estimate the welfare costs (net social losses) for the eight commodities listed in table 1. We first calculate the welfare costs in 1975/76, then compare them with the current welfare costs of the 1985/86 production plan, assuming that the output goals are met. To make this latter estimate, we assume that the producer prices in 1975/76 were increased through government support prices and that consumer food prices were maintained at current levels. Such assumptions are based on recent Japanese agricultural policy.[2]

Estimation Technique

The basic formulae for calculating the net social loss in consumption (NSL_c) and the net social loss in production (NSL_p) of price distortions are given in equations 1 and 2, respectively:

(1) $$NSL_c = ½(P_d - P_w)(Q_w - Q_d),$$

and

(2) $$NSL_p = ½(P'_d - P'_w)(Q'_d - Q'_w),$$

where P_w = world price at retail, P_d = domes-

[1] Unlike other writers (e.g., Barker and Hayami, Sanderson) we resist the temptation of using the phrase "food self-sufficiency" as a substitute for "food production." Without reference to prices, the phrase "self-sufficiency" clearly has no meaning in the economists' lexicon.

[2] Split years denote Japan's fiscal years (April–March).

Table 1. Production, Consumption, and Imports of Principal Food Commodities

	Production		Consumption		Imports	
	1975/76	1985/86[a]	1975/76	1985/86[b]	1975/76	1985/86[c]
	1,000 tons					
Wheat	241	553	5,578	5,899	5,715	5,346
Rice[d]	13,165	12,110	11,964	12,110	29	0
Soybeans[e]	126	427	3,502 (692)	5,007 (707)	3,334	4,580
Barley[f]	221	890	2,195 (1,019)	2,502 (996)	2,117	1,612
Dairy products[g]	5,010	7,680	6,125	8,142	787	462
Pork	891	1,325	1,058	1,332	208	10
Chicken	756	914	781	915	28	1
Beef	327	508	407	625	91	117

Source: Japan, Government of, Ministry of Agriculture and Forestry. *Food Balance Sheet.* Tokyo, Nov. 1976 (for actual data for 1975/76). Ministry of Agriculture and Forestry. *Long-Term Prospect of Production and Demand of Agricultural Products in Japan.* Tokyo, Aug. 1975 (for data on production goals and consumption estimates for 1985/86).

[a] Production goals.
[b] Consumption estimates by the Ministry of Agriculture and Forestry.
[c] Inferred from production goals and consumption estimates assuming no change in stocks and no exports.
[d] Brown basis.
[e] Numbers in parentheses exclude soybeans for crushing.
[f] Numbers in parentheses exclude barley for feed.
[g] In raw milk equivalent.

tic retail price, Q_d = domestic consumption at domestic prices, Q_w = domestic consumption if world price prevailed, P'_d = domestic producer price, P'_w = world producer price, Q'_d = domestic production at domestic prices, and Q'_w = domestic production that would be forthcoming at world prices.

Information required to complete the analysis are world and Japanese prices (table 2) and estimates of supply and demand functions by commodity for Japan (table 3). The world and Japanese prices shown in table 2, taken from Bale and Greenshields, are used to calculate net welfare losses. Retail prices are used to calculate net social losses in consumption, and producer prices are used to calculate net social losses in production. Use of wholesale prices would overestimate net social loss in production. For grains and soybeans for food use, the landed price for Japan is the same as the potential world retail price in Japan. World retail prices of dairy and livestock are found by applying the existing Japanese wholesale/retail margin to the landed price in Japan for the relevant commodities. In the interest of brevity, the behavioral reasons for structuring the equations as displayed in table 3 are not presented. They are discussed in Bale and Greenshields.

Substituting world prices into the supply and demand equations allows us to estimate a level of consumption and production that would obtain in the absence of trade barriers and price supports. With this information, the net social loss may be calculated.

To find the net social loss of the 1985/86 level of production in terms of current prices, we merely substitute the production goal into the supply equation to obtain an implicit price that is required to bring forth that level of production.

Results

The net social losses in consumption and production of selected agricultural products in Japan for 1975/76 and for 1985/86 (at 1975/76 prices) are displayed in table 4. Consumption losses range from a high of 32 billion yen for dairy products to 415 million yen for soybeans, while production losses in 1975/76 range from 17 billion yen for rice to 49 million yen for poultry (302 yen = U.S. $1.00). In general, the ranking of the total net social losses in 1975/76 corresponds to what we might expect. The protected livestock industries (except the relatively efficient poultry industry) and rice incur the highest losses, and wheat and soybeans, which are virtually all imported, incur the smallest losses.

The effect on social losses of the 1985/86 production goals is dramatic. Net social costs in production would increase to 2.3 trillion yen (U.S. $7.6 billion). Livestock products and soybeans are the major contributors, while the net social loss of the rice support program would decline under the future plan.[3] Overall, for the eight commodities analyzed here, net social losses would increase from 117 billion yen in 1975/76 to 2.4 trillion yen in 1985/86. If the 1985/86 production goals were implemented, the total net social losses would be equivalent to 2% of Japan's gross national

[3] Probably not to zero as indicated in the table, however. Because of the inelastic price response measured from the limited range of data in our sample, there was no positive price that would satisfy the supply equation for the 1985/86 production goal.

Table 2. Comparison of Japanese and World Prices

	Japanese Price		World Price[a]	
Commodity	Producer	Retail	Producer	Retail
	Yen/Ton			
Wheat	112,000	46,553	56,179	56,179
Rice	229,000	189,880	112,770	112,770
Soybeans[b]	145,417	145,417	90,144	90,144
Barley[c]	98,324	34,933	47,454	47,454
Milk[d]	91,300	227,510	66,070	171,340
Pork	501,200	1,550,000	336,000	1,071,000
Chicken	290,900	990,000	323,561	789,174
Beef	865,800	2,710,000	667,975	1,967,490

[a] World prices are calculated from the world price (landed in Japan) of the nearest equivalent quality and type of good produced in Japan.
[b] Only food-use soybeans.
[c] Only barley used in food (including malting).
[d] Calculated on a milk equivalent basis assuming no international trade in fluid milk.

Table 3. Estimated Demand and Supply Functions

Commodity	Equations	n	R^2	$C.V.$	d	$\epsilon(P)$	$\epsilon(I)$
Wheat	$Y_1 = 5016.48 - 813.410(X_1/X_2/X_3) + 12.2926(X_4/X_5)$ (18.63) (4.77) (6.32)	15	0.96	2	1.76	−0.16	0.15
	$Y_2 = 79022.4 + 1430.68(X_6/X_7/X_8/X_9)_{t-1}$ (5.23) (5.44)	22	0.91	15	1.39	1.61	
	$- 40.5533\, X_{10} - 660.325\, X_{11} + 622.133\, X_{12}$ (5.34) (4.07) (3.24)						
Rice	$Y_3 = 16563.8 - 1089.70(X_8/X_1/X_3) - 43.0688(X_4/X_5)$ (23.17) (3.86) (7.54)	15	0.89	2	1.83	−0.12	−0.21
	$X_4 = -18.3433 + 18.99(X_{13}/X_{14}/X_8/X_9)_{t-1}$ (4.24) (3.48)	24	0.77	6	1.52	0.16	
	$+ 98.7797\, X_{10} - 2358.07\, X_{15}$ (4.49) (5.05)						
Soybeans	$Y_5 = 537.851 - 60.0182(X_{17}/X_1/X_3) + 1.69923(X_4/X_5)$ (4.63) (1.16) (2.10)	15	0.86	4	1.16	−0.14	0.18
	$Y_6 = 30892.8 + 99.2990(X_{14}/X_{13}/X_8/X_9)_{t-1}$ (6.92) (2.94) $- 15.6541\, X_{10} - 50.8451\, X_{15} + 87.2884\, X_{12}$ (6.95) (2.41) (3.31)	24	0.95	11	1.57	0.46	
Barley	$Y_7 = 1230.45 - 259.416(X_{17}/X_{19}/X_{18})$ (11.87) (2.97)	13	0.95	8	1.82	−0.51	−1.23
	$- 8.45516(X_4/X_5)$ (14.53)						
	$Y_8 = 916.815 - 0.651812(X_{20}/X_3) + 3.73795(X_4/X_5)$ (3.18) (3.10) (3.33)	11	0.97	5	1.40	−1.28	0.51
	$Y_9 = 223487 + 630.094(X_7/X_6/X_8/X_9)_{t-1}$ (16.69) (2.93)	22	0.98	10	1.43	0.55	
	$- 113.459\, X_{10} - 851.991\, X_{11} + 476.263\, X_{12}$ (16.87) (6.46) (3.08)						
Milk	$Y_{10} = 6847.78 - 168.349(X_{21}/X_3) + 41.9269(X_4/X_5)$ (4.08) (3.03) (15.32)	14	0.98	3	1.18	−1.00	0.55
	$Y_{11} = -83674.9 + 1964.39(X_{22}/X_{23})_t$ (1.80) (3.18)	10	0.96	2	1.67	0.43	
	$- 1403.03(X_{22}/X_{23})_{t-1} + 2038.08(X_{22}/X_{23})_{t-2}$ (2.36) (3.16)						
	$+ 42.0772\, X_{10}$ (1.75)						
Pork	$Y_{12} = 504.819 - 469.074(X_{24}/X_{25}/X_3) + 9.87347(X_4/X_5)$ (4.29) (5.52) (16.86)	14	0.99	5	1.37	−0.76	0.97
	$Y_{13} = -86224.9 - 196.347(X_{26}/X_{27}/X_{28}/X_9)_t$ (5.68) (2.54)	10	0.92	7	1.71	0.14	
	$+ 106.387\, (X_{26}/X_{27}/X_{28}/X_9)_{t-1} + 44.1560\, X_{10}$ (1.38) (5.75)						
Chicken	$Y_{14} = -104.793 - 114.437(X_{25}/X_{24}/X_3)$ (1.06) (2.66)	8	0.99	1	2.75	−0.15	1.33
	$+ 10.1262(X_4/X_5)$ (12.38)						
	$Y_{15} = -165825 + 126.709(X_{27}/X_{26}/X_{29}/X_9)_t$ (7.13) (1.67)	10	0.99	4	1.84	0.12	
	$+ 67.0063(X_{27}/X_{28}/X_{29}/X_9)_{t-1} + 84.3337\, X_{10}$ (0.89) (7.17)						

Table 3. *(Continued)*

Commodity	Equations	n	R^2	$C.V.$	d	$\epsilon(P)$	$\epsilon(I)$
Beef	$Y_{16} = 286.964 - 140.939\,(X_{30}/X_{24}/X_3) + 2.82836(X_4/X_5)$ (6.56) (5.97) (11.56)	16	0.96	7	1.40	−0.80	0.66
	$Y_{17} = -28979.0 - 89.9772(X_{31}/X_{22}/X_9)_t$ (2.64) (1.04)	10	0.72	15	1.92	0.66	
	$+\ 156.679(X_{31}/X_{23}/X_9)_{t-3} + 14.7911\,X_{10}$ (0.71) (2.65)						

Note: Endogenous variables (units = 1,000 tons): Y_1 = wheat consumption, Y_2 = wheat production, Y_3 = rice consumption, Y_4 = rice production, Y_5 = soybean consumption, Y_6 = soybean production, Y_7 = food barley consumption, Y_8 = malting barley consumption, Y_9 = barley production, Y_{10} = dairy product consumption, Y_{11} = milk production, Y_{12} = pork consumption, Y_{13} = pork production, Y_{14} = chicken consumption, Y_{15} = broiler production, Y_{16} = beef consumption, and Y_{17} = beef production. Exogenous variables: X_1 = retail bread price, Tokyo, yen per kilogram; X_2 = retail rice price, Tokyo, yen per kilogram; X_3 = consumer price index, all Japan, 1970 = 1; X_4 = gross national production (GNP), trillion yen; X_5 = implicit GNP price deflator, 1970 = 1; X_6 = producer wheat price index, 1970/71 = 1,000; X_7 = producer barley price index, 1970/71 = 1,000; X_8 = retail fertilizer price index, 1970/71 = 1; X_9 = producer input price index, 1970/71 = 1; X_{10} = time trend, 1950/51 = 1950, etc.; X_{11} = dummy variable representing unusually low yields not directly attributable to included economic variables, zero when not applicable, one in 1963/64; X_{12} = dummy variable representing the government program to increase wheat, soybeans, and barley production, zero through 1973/74 and one thereafter; X_{13} = producer rice price index, 1970/71 = 1,000; X_{14} = producer soybean price index, 1970/71 = 1,000; X_{15} = dummy variable representing unusually low yields not directly attributable to included economic variables, zero when not applicable, one in 1953/54, 1954/55, and 1971/72; X_{16} = retail *miso* price, Tokyo, yen per kilogram; X_{17} = wholesale barley price index, 1970 = 1,000; X_{18} = wholesale wheat flour price index, 1970 = 1,000; X_{19} = wholesale price index, 1970 = 1; X_{20} = retail beer price index, Tokyo, 1970 = 1,000; X_{21} = wholesale milk price, Tokyo, yen per 200 milliliters; X_{22} = producer milk price index, 1970/71 = 1,000; X_{23} = retail dairy cattle feed price index, 1970/71 = 1,000; X_{24} = retail pork price index, Tokyo, 1970 = 1,000; X_{25} = retail chicken price index, Tokyo, 1970 = 1,000; X_{26} = producer swine price index, 1970/71 = 1,000; X_{27} = producer broiler price index, 1970/71 = 1,000; X_{28} = retail swine feed price index, 1970/71 = 1; X_{29} = retail broiler feed price index, 1970/71 = 1; X_{30} = retail beef price, Tokyo, yen per kilogram; and X_{31} = producer beef cattle price index, 1970/71 = 1.

product or one-third of each household's expenditures on the eight commodities or their products.

Concluding Comment

Government policies which interfere with the free interplay of market forces are a common feature of modern economic life. Such policies are often imposed for political, social, or economic reasons on the assumption that the benefits derived from the policies exceed the economic costs of them. In the case of Japan, there are numerous benefits to be gained from maintaining and possibly increasing the large agricultural complex. Among those frequently cited are benefits pertaining to food security—the interdiction of trade because of war, the world "food shortage," agricultural price instability, and oligopolistic behavior by agricultural exporters (Sanderson). Without information on the national cost of various levels of domestic production, it is impossible for policymakers to make informed decisions on the advisability of a given level of production. This article has presented calculations on the social cost of achieving two levels of Japanese agricultural production by government intervention. Such cost estimates should

Table 4. Net Social Loss Incurred in Consumption and Production of Selected Agricultural Commodities in Japan

	(1)	(2)	(3)	(4)	(5)	(6)
Commodity	NSL_c (1975/76)	NSL_p (1975/76)	NSL'_p (1985/86)	(3) − (2) NSL_p (marginal)	(1) + (2) NSL (total) (1975/76)	(1) + (3) NSL (total) (1985/86)
	Billion yen					
Wheat	0.496	0	25.552	25.552	0.496	26.048
Rice	9.292	16.505	0	−16.505	25.797	9.292
Soybeans	0.415	0.332	248.916	248.584	0.747	249.331
Barley	1.672	3.179	97.873	94.694	4.851	99.545
Milk	31.652	10.319	176.830	166.511	41.971	208.482
Pork	26.345	1.156	1,119.604	1,118.448	27.501	1,145.949
Chicken	1.004	0.049	359.134	259.085	1.053	260.138
Beef	12.623	1.880	366.442	364.562	14.503	379.065
Total	83.499	33.420	2,294.351	2,260.947	116.919	2,377.850
	Million dollars					
Total	276	111	7,597	7,486	387	7,873

facilitate an enlightened debate on whether Japan's agricultural production goals do or do not have a favorable benefit/cost ratio.

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A Model for Evaluating the Effects of Thai Government Taxation of Rice Exports on Trade and Welfare

Chung Ming Wong

The implications of Thai government taxation of rice exports through the export premium on trade and welfare are examined by means of a dynamic simultaneous equation model which allows for interactions between the rice production, consumption, and export sectors. Although the export premium may have generated a net welfare gain for Thailand over the 1961–70 period, owing to the highly imperfect nature of the international market, it results in a substantial transfer from the farmers and may have adverse effects on their incentives to adopt modern inputs in paddy production.

Key words: model, rice export, taxation, Thailand, welfare.

The international market for rice is of a highly residual nature. Only about 5% of world production is traded, and this amount is differentiated by marked preference of buyers for certain varieties, and by the fact that about one-third of international trade is under concessional terms or direct government-to-government contracts (Timmer and Falcon). The rice economies in Asia, which account for 90% of world production and 70% of international trade, are characterized by a high degree of government intervention in production, export, and internal distribution. Many countries have supported the domestic price to drive towards self-sufficiency; others have tried to stabilize it at low levels to benefit consumers. Because of the setting of domestic prices to fulfill certain national objectives, the burden of price adjustment has to be borne by the international market, causing sharp fluctuations in international prices when poor harvests in major exporting or importing countries lead to rather sudden changes in export supply or import demand (Johnson).

In the postwar period, Thailand has ranked as one of the world's largest rice exporters. From 1950 to 1955, a multiple exchange rate system was in operation and the export of rice was under government monopoly. This monopoly was abolished in 1955, and the export premium, a fee to be paid as a price for obtaining an export license and in effect an export tax, became the major instrument of government intervention.[1] Government-to-government rice exports were suspended in 1955 but later restored, averaging about 30% to 40% of total exports.[2] The export premiums on most grades of rice were temporarily removed in April 1971 but later restored. In 1973 and 1974, with diminished world stocks and the international monetary crisis, export premiums were raised to combat domestic price inflation. In addition to the export premium, the government has sometimes resorted to

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[1] During the period of the multiple exchange rate system, the rice premium applied only to commercial exports (about 5% of total rice exports). Two other components of the tax burden are more important. First, commercial exporters had to buy rice from the government at prices 15% to 20% higher than the government purchase price. Second, foreign exchange earnings of the government's Rice Bureau were converted at the official exchange rate, and those of commercial exporters had to be surrendered to the Bank of Thailand at the official exchange rate according to government export prices (usually somewhat lower than commercial prices). Since the official exchange rate was far below the free market rate during this period, this results in a profit to the government (Sanittanont, Yang). In estimating the model, all three components are taken into account during the period 1951–54.

[2] In the case of government-to-government exports, the government negotiates the terms with foreign governments and procures rice at official prices which are lower, thus generating a profit which is analogous to the rice premium. This is paid by the government to the government agency collecting the premium.

quantitative controls and regulation of exporters.[3]

The proponents of the export premium argue that it is an important source of government revenue and that the burden is mainly borne by foreigners.[4] Its critics claim that the tax burden is easily shifted back to the farmer in the form of lower prices and it therefore creates a serious disincentive to increasing rice production. In spite of the long history of debate on the export premium, however, not much empirical work has been done to measure its effects quantitatively. Although Sanittanont analyzed various issues concerning the export premium, he was primarily concerned with its effects on income distribution and did not actually estimate those demand and supply elasticities crucial to his conclusions. This paper makes use of a simple econometric model to measure the welfare and transfer effects of the export premium.[5]

[3] More recently, for certain grades of rice, exporters have been required to sell a fixed proportion to the government for every ton exported in order to ensure adequate supplies for domestic consumption. See Somboonsup and Welsch for details.

[4] In 1960, for example, rice premiums accounted for 12.0% of total government revenue, while income tax yields (personal and corporate) accounted for only 9.4%. It was not until 1966 that receipts from the income taxes accounted for more than receipts from rice premiums (Bangkok Bank Limited, p. 294).

[5] In this paper we shall not consider the effect of the export premium on the stability of prices in the international and domestic markets. Ingram (pp. 250–52) finds that the export premium has not stabilized the domestic price to any significant extent.

Theoretical Framework

The welfare and transfer effects of the export premium may be quantified using the producer and consumer surplus techniques recommended by Harberger.[6] In figure 1, the export supply curve S_x is the horizontal difference between the domestic supply curve S_d and the domestic demand curve D_d, neglecting stock changes. The foreign demand curve for Thai rice, D_f, is shown as downward sloping. We have seen earlier that, because of the residual nature of the rice trade, international prices are mainly determined by the volume of world export. Thus, Thailand, as the largest commercial exporter, may exert some influence on international prices even though it is not among the world's largest rice producers. Moreover, the considerable market specialization among the major exporters, the presence of exports under long term government-to-government contracts, the marked preference for Thai rice in some markets because of its high quality, and the close connection between Thai exporting firms and merchants in the major importing countries all help to explain why at least in the short run foreign demand for Thai rice may not be perfectly

[6] For an example of the empirical application of such techniques to quantify welfare effects in a similar context, see Haessel and Vickery.

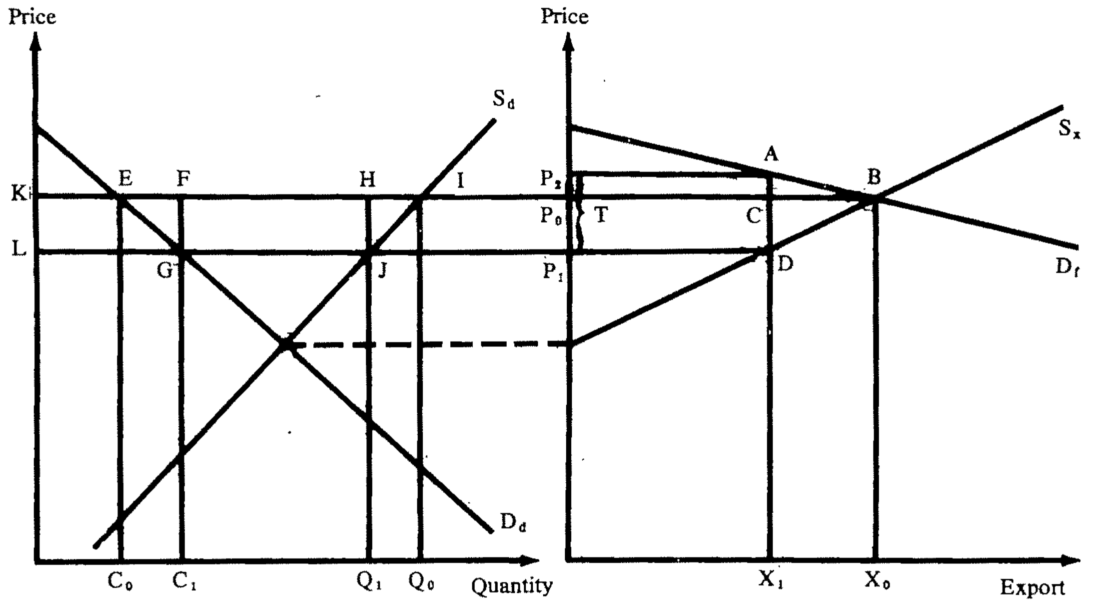

Figure 1. Welfare and transfer effects of the export premium

elastic. Therefore, when the export premium T is imposed, the export price rises from P_0 to P_2, and the domestic price falls from P_0 to P_1. Production is reduced from Q_0 to Q_1, consumption increases from C_0 to C_1, and the volume of export falls from X_0 to X_1. Foreign exchange earnings change by area ACP_0P_2 minus area CBX_0X_1. There is a reduction of the "producer surplus" of rice farmers by area $IJLK$ only partially offset by a gain in government revenue at the expense of domestic citizens of $FHJG$. This leaves areas HIJ and EFG (whose sum is equal to CBD) as deadweight losses, the former being the production loss and the latter being the consumption cost. Area ABP_0P_2 is the loss in consumer surplus of the foreigner, out of which ACP_0P_2 is collected by the Thai government and ABC is a deadweight loss from an international point of view.

As long as the foreign demand for Thai rice is not perfectly elastic, there is an optimum export tax which would maximize the welfare of Thailand, or the gain in government tax revenue at the expense of foreigners minus welfare losses ($ACP_0P_2 - HIJ - EFG$). This gain is necessarily positive at low rates of export tax but may turn negative at high rates.

The size of the net gain or loss from imposing the export premium depends on the domestic and foreign elasticities of supply and demand, for they determine the relative burden borne by foreigners and by domestic citizens. It also depends on the length of run considered because welfare losses would be higher if elasticities increase in the long run. The following model takes these factors into account.

The Model

The model, formulated in aggregate terms, consists of four equations (a domestic supply equation, a domestic consumption equation, an export price equation, and a price transmission equation) and two identities (a market clearing identity and an identity defining the export price net of rice premium). There are six endogenous variables, three lagged endogenous variables, and eleven exogenous variables. The endogenous variables are Q_t = domestic production of milled rice; P_{dt} = domestic wholesale price of milled rice; C_t = domestic consumption of milled rice; X_{Tht} = volume of milled rice export from Thailand; P_{wt} = export price; and P_{et} = export price minus export premium. The lagged endogenous variables Q_{t-1}, P_{dt-1}, and C_{t-1} are Q_t, P_{dt}, and C_t lagged one period, respectively. The exogenous variables are W_t = percentage of paddy area damaged in crop year t; P_{ct-1} = lagged price index of all crops except rice; t = trend term (1951 = 1); Y_t = national income; I_{at} = sum of U.S. Public Law 480 rice exports and net rice export from Japan; I_{bt-1} = index of per capita paddy production of six major importing countries, lagged one crop year; g_t = percentage of rice export from Thailand under government-to-government contracts; D_t = dummy variable, set equal to one for years 1951 to 1955, and zero for other years; ΔS_t = addition to rice stocks during the year; T_t = export premium; and P_{nt} = price index of substitute foods in consumption. It should be noted that the small letter t, when appearing as a subscript, denotes the time period—crop years for agricultural production statistics and calendar years for most other statistics. Prices, income, and export premium rates have been deflated by the wholesale price index with 1960 as base.

The specification of the model is as follows. The domestic supply equation is

$$(1)\quad Q_t = \gamma_{10} + \gamma_{11}Q_{t-1} + \gamma_{12}P_{dt-1} + \gamma_{13}P_{ct-1} + \gamma_{14}W_t + U_{1t}.$$

The domestic consumption equation is

$$(2)\quad C_t = \gamma_{20} + \gamma_{21}C_{t-1} + \gamma_{22}t + \gamma_{23}P_{nt} + \gamma_{24}Y_t + \beta_{21}P_{dt} + U_{2t}.$$

The export price equation is

$$(3)\quad P_{wt} = \gamma_{30} + \gamma_{31}I_{at} + \gamma_{32}I_{bt-1} + \gamma_{33}g_t + \gamma_{34}D_t + \beta_{31}X_{Tht} + U_{3t}.$$

The price transmission equation is

$$(4)\quad P_{dt} = \gamma_{40} + \gamma_{41}D_t + \beta_{41}P_{et} + U_{4t}.$$

The market clearing identity is

$$(5)\quad X_{Tht} = Q_{t-1} - C_t - \Delta S_t;$$

and the export price net of rice premium is

$$(6)\quad P_{et} = P_{wt} - T_t.$$

Note that the coefficients of endogenous variables are represented by β's and those of predetermined (exogenous and lagged endogenous) variables are represented by γ's. The U's represent random residuals.

Equation (1) is the familiar Nerlovian supply equation with adaptive expectations. The

quantity of rice produced is regarded as a function of the expected prices of rice and of competitive crops. Expectations are updated each period by a fraction of the discrepancy between last period's observed value of the variable and the previous expected value. The weather variable W_t is used to take into account chance factors like floods or droughts.

Equation (2) regards desired rice consumption as a function of current income and prices, but asserts that only part of the adjustment towards this equilibrium level would be completed this period (Nerlove). Consumption figures are estimated using the formula $C_t = Q_{t-1} - X_{Tht} - (S_t - S_{t-1})$, where S_t and S_{t-1} are the end-of-year stocks of calendar years t and $t-1$ respectively.[7] The trend term is included to take into account miscellaneous factors like changes in age and income distribution, changes in taste, and so on.

In equation (3), the export price of Thailand is a function of its rice export. The indicators I_{at} and I_{bt-1} take into account, respectively, the effect of concessional sales and sales by unusual exporters like Japan, and the effect of the drive towards self-sufficiency by traditionally importing countries. The variable g_t is an indicator of Thai government policy other than the export premium. The dummy variable, D_t, takes into account the abnormal conditions under the multiple exchange rate system from 1951 to 1955.

Equation (4) postulates a relation between the export price net of export premium and the domestic price. Identity (5) is the market clearing identity. In the model, stock changes are regarded as exogenous and exports are treated as the residual.[8]

There are six equations in the model and six endogenous variables. The order and rank conditions of identifiability are both satisfied. The model is block-recursive with two groups of equations. Rice production is determined in the first equation, while export, consumption, export price, and domestic price are simultaneously determined in the other equations. According to the identifiability criteria for block-recursive systems (Fisher), equation (1) is exactly identified and equations (2) to (4) are overidentified. The two-stage least squares method is used to provide consistent estimates of the structural coefficients in equations (2) to (4). In the supply equation, there is only one endogenous variable and therefore ordinary least squares is used.[9]

The data used in fitting the model are obtained mainly from Thailand Ministry of Agriculture, Bank of Thailand, and FAO sources. The period of our analysis is from 1951 to 1972. Thus there are twenty-two observations in each regression. The estimates of the structural coefficients are presented in table 1, with their standard errors also shown.[10] The signs of all estimated coefficients are consistent with expectations. The various price and income elasticities are shown in table 2.

Results in tables 1 and 2 show that production adjusts rather slowly to price changes, but the long-run elasticity of supply is fairly high.[11] It is also seen that the percentage of area damaged has a very important effect on Thailand's total paddy production. Consumption adjusts rather rapidly, but both price and

[7] The stock figures, which come from FAO, include only stocks of the old crop available for export. Thus private stocks (often discouraged by the government), together with seed, animal feed, and industry uses, as well as wastage during storage and export have been included in our C_t figures.

[8] Although changes in stocks would presumably depend on some of the variables in the system, the decision to build up or deplete stocks is influenced by a set of very complicated and diverse factors (like projected future shortages, anticipated improvement in external markets, and so on) and there do not seem to be particularly important variables that deserve to be singled out to explain stock changes in a model fitted with annual data. Moreover, data on stocks for developing countries are subject to large errors, and attempts to fit an equation to explain stock changes have not been satisfactory. Since our data on stocks represent mainly stocks held by exporters, a large part of the accumulation or depletion of stocks could indeed be regarded as exogenous, reflecting government interventions, like quotas and temporary export controls. For these reasons, stock changes are best regarded as exogenous. Since they are only a small percentage of annual production because of the lack of storage facilities, our results would not be much affected by this assumption.

[9] It should be noted that when a lagged dependent variable is present as a regressor, OLS gives inconsistent estimators when problems of autocorrelated disturbances are suspected. See Johnston (pp. 303–20) for a good discussion of these problems.

[10] Since two-stage least squares is used in equations (2) to (4), the usual tests of significance are not really applicable. But standard errors are nevertheless presented to give some rough indication of the statistical significance of the estimates. Since OLS is used in equation (1), Durbin's h-statistic may be used to test for positive serial correlation of residuals. Using a one-tail test, the computed h has a probability value of 0.41, implying that the null hypothesis of no autocorrelation cannot be rejected under the usually accepted levels of significance. It should be noted, however, that Durbin's method is essentially a large sample test which may not be applicable here because there are only twenty-two observations.

[11] Using a non-linear estimation procedure to estimate supply response for an earlier period (1940–63), Behrman finds that for the kingdom as a whole, the elasticity of acreage planted with respect to price (ϵ_{AP}) is 0.18 in the short run and 0.31 in the long run. Of course, the elasticity of output with respect to price should be higher because any effect of price changes upon yield per unit area has not yet been taken into account. Behrman (p. 154) notes that, assuming the farmer has control over the area which is planted so that planned planted area A* is always equal to actual planted area A, the relationship $\epsilon_{Q^*P} \cong \epsilon_{AP} + \epsilon_{Y^*P}$ should hold, where ϵ_{Q^*P} is the elasticity of planned output with respect to price and ϵ_{Y^*P} is the elasticity of planned production per unit planted area with respect to price.

Table 1. Two-Stage Least Squares Estimates of Structural Equations

No.	Estimated equation
1[a]	$Q_t = 3914.72 + 0.5538\, Q_{t-1} + 1.5132\, P_{dt-1} - 16.4382\, P_{ct-1} - 209.2310\, W_t$
	(0.1034) (0.9391) (3.4439) (29.6882)
	$R^2 = 0.8863$ $h = 0.23$
2	$C_t = 4185.89 + 0.0814\, C_{t-1} - 1.2458\, P_{dt} + 6.5629\, P_{wt} + 132.7350\, t + 0.0087\, Y_t$
	(0.2675) (1.5074) (10.9385) (188.1360) (0.0446)
3	$P_{wt} = 4333.72 - 0.1290\, I_{at} - 8.0655\, I_{bt-1} + 10.1850\, g_t + 340.2620\, D_t - 0.5322\, X_{Tht}$
	(0.1179) (11.6027) (5.0565) (275.7180) (0.1806)
4	$P_{dt} = 914.10 + 355.4730\, D_t + 0.4233\, P_{et}$
	(64.5008) (0.1497)

Note: Standard errors in parentheses. See note 10 about test statistics.
[a] Estimated by ordinary least squares (OLS).

income elasticities are low.[12] The estimate of the foreign elasticity of demand, using the inverse of the price flexibility estimate, is about four. Since the price dependent form of equation (3) tends to overestimate the true elasticity, this lends strong support to the hypothesis that foreign demand is not infinitely elastic.[13] A possible interpretation of the positive coefficient for g_t is that a high g_t indicates strong foreign demand, since contracts have usually been made at the request of buying countries. The good fit of equation (4) implies that because of the comparative lack of government intervention on the rice economy other than the export premium during the period of our analysis, the export and domestic markets of Thailand, unlike those in most Asian countries, are fairly well integrated.This implies if the export premium cannot be passed on to the foreign buyers to any great extent, it has to be borne eventually by the farmers in the form of lower farm prices.

The Effects of the Export Premium

The Mechanism of the Model

The mechanism of the model may be examined through the reduced and final forms of the model. The impact multipliers of a change in the export premium are shown in table 3. It should be noted that except for the first row, all other impact multipliers have the common factor $\frac{1}{Z}$ which embodies the interaction mechanism of the model and can be seen to consist of several partial derivatives, or

$$\frac{1}{Z} = 1\Big/\left\{1 - \left(\frac{\partial C_t}{\partial P_{dt}}\frac{\partial P_{dt}}{\partial P_{et}}\frac{\partial P_{et}}{\partial P_{wt}}\frac{\partial P_{wt}}{\partial X_{Tht}}\frac{\partial X_{Tht}}{\partial C_t}\right)\right\} \doteq \frac{1}{1-m}.$$

As an illustration, the export premium tends to reduce P_{et} by the same amount. This is, in

[12] Behrman (p. 313) also reports that there is no evidence of any significant response of rice consumption to relative price or income changes in the 1947–62 period.

[13] It is interesting to note that the range of fluctuations of international grain prices in 1973–75 lies far outside the range of observations over which the model is estimated. Thus, it is possible that some exogenous variable not included in the model may have a significant impact on the export market, and one should therefore be careful in making predictions.

Table 2. Estimates of Elasticities at Means

Elasticities	Short run	Long run
(1) Price elasticity of supply	0.4065	0.9110
(2) Cross price elasticity of supply	−0.2799	−0.6273
(3) Price elasticity of demand	−0.4285	−0.4665
(4) Cross price elasticity of demand	0.1484	0.1616
(5) Income elasticity of demand	0.0935	0.1018
(6) Foreign elasticity of demand[a]	−3.9994	
(7) Elasticity of price transmission	0.4477	

[a] Inverse of price flexibility estimate.

Table 3. Impact Multipliers of a One Unit Change in the Export Premium

Endogenous variables	Impact multipliers	
	Formulas	Numerical values
Q_t	0	0.0000
P_{dt}	$-\frac{1}{Z}\beta_{41}$	−0.3305
C_t	$-\frac{1}{Z}\beta_{21}\beta_{41}$	0.4118
X_{Tht}	$\frac{1}{Z}\beta_{21}\beta_{41}$	−0.4118
P_{wt}	$\frac{1}{Z}\beta_{21}\beta_{31}\beta_{41}$	0.2191
P_{et}	$-\frac{1}{Z}$	−0.7809

Note: $Z = 1 + \beta_{21}\beta_{31}\beta_{41}$.

turn, reflected in a fall in the domestic price, and the resulting increase in consumption and reduction in export supply tend to raise the export price and thus reverse the original fall in P_{et}. Since m is negative, this would give rise to oscillations which would damp down, however, as long as $|m| < 1$.[14] It is interesting to note that the model has the property that the rise in P_{wt} and the fall in P_{et} together account for the full amount of the export premium, or differentiating identity (6), on both sides:

$$\frac{\partial P_{wt}}{\partial T_t} - \frac{\partial P_{et}}{\partial T_t} = \frac{1}{Z}(\beta_{21}\beta_{31}\beta_{41} + 1) = 1.$$

The impact, interim, and total multipliers of a unit change in the export premium, easily derived from our estimates of the structural coefficients, are shown in table 4. The impact multipliers in line one show that, in the current period, about 20% of an increase in the export premium would be reflected in a rise in the price paid by foreign buyers, and about 80% would be reflected in a fall in P_{et} (which is then reflected in a fall in the domestic price). The relatively small effect on the export price in the current period is due to the fact that, with a given supply, the volume of export could be reduced only by increasing consumption that is price inelastic. In the longer run, however, the major effect on export supply and export price is through the smaller output as a result of the export premium. Since production adjusts rather slowly, the effect is spread over a number of years, but the effects on the various variables become rather insignificant after several years. Because the export premium results in smaller future crops, in the long-run equilibrium, as much as 50% of it may be passed on to foreigners, as shown by the total multipliers in table 4.[15]

[14] It should be noted that $\frac{\partial P_{et}}{\partial P_{wt}}$ and $\frac{\partial X_{Tht}}{\partial C_t}$ are, respectively, equal to 1 and −1.

[15] This estimate, however, is based on rather unrealistic as-

Table 4. Effect of a Unit Change in the Export Premium

Year	Q_t	P_{dt}	C_t	X_{Tht}	P_{wt}	P_{et}
	Endogenous Variables					
1	0.0000	−0.3305	0.4118	−0.4118	0.2191	−0.7809
2	−0.5001	0.0059	0.0262	−0.0262	0.0139	0.0139
3	−0.2680	0.0883	−0.1079	−0.3922	0.2087	0.2087
4	−0.0148	0.0456	−0.0656	−0.2024	0.1077	0.1077
5	0.0608	0.0017	−0.0074	−0.0074	0.0039	0.0039
6	0.0362	−0.0108	0.0129	0.0479	−0.0255	−0.0255
7	0.0037	−0.0062	0.0088	0.0274	−0.0146	−0.0146
8	−0.0073	−0.0005	0.0014	0.0023	−0.0012	−0.0012
9	−0.0048	0.0013	−0.0015	−0.0058	0.0031	0.0031
10	−0.0007	0.0008	−0.0011	−0.0037	0.0019	0.0019
Total Multi-plier	−0.6936	−0.2045	0.2775	−0.9711	0.5167	−0.4833

Note: Quantities in thousand metric tons. Prices and export premium rates in baht per metric ton.

Measurement of Welfare and Transfer Effects

The welfare and transfer effects of the export premium shown in figure 1 may easily be quantified using the following formulas:

(7) production loss $= \frac{1}{2}\,\Delta Q \Delta P_d$;

(8) consumption cost $= -\frac{1}{2}\,\Delta C \Delta P_d$;

(9) transfer from Thai farmers $= \frac{1}{2}\,\Delta Q \Delta P_d - Q\Delta P_d$;

(10) transfer from foreigners $= X_{Th}\Delta P_w$;

and

(11) change in foreign exchange earnings $= \Delta P_w X_{Th} + (\Delta Q - \Delta C)(P_w - \Delta P_w)$,

and by applying linear approximation to the curves. Q, X_{Th}, and P_w all refer to values in the presence of the export premium, and all changes refer to the long run. Since export premium rates, prices, and quantities vary considerably over time, welfare changes and transfers are evaluated using average values of these variables for the period 1961–70. Since prices and export premium rates in the model have been deflated, welfare changes and transfers are estimated at 1960 prices.[16]

We have seen earlier that, as a result of the export premium, there are welfare costs owing to distortions in the patterns of production and consumption. However, there is an offsetting gain through government revenue collected from foreigners in the form of higher prices. The crucial determinant of the net gain or loss is, therefore, the relative burden borne by foreigners and by domestic citizens. This depends on the extent foreign demand is more price-responsive in the long run than in the short run. Although it might be possible for Thai exporters to raise price in the short run without a significant loss of markets, buyer's preference and the present institutional arrangements may break down over time so that importers shift to alternative suppliers or strengthen their self-sufficiency policies. Of even greater importance in determining the possible gains from removing the premium, however, is the degree of liberalization of the international market in the future. Case A of table 5 represents a hypothetical free-trade situation, in which case Thailand, as a small producer, would not be expected to have a strong influence on world prices. It appears reasonable to assume that under such conditions, the change in world price as a percentage of the export premium, μ, would probably be not more than 5%.[17] On the other hand, case D, representing the other extreme, quantifies welfare effects and transfers, using directly those predictions of change in prices and quantities by the total multipliers in table 4 which assume that the characteristics of both the international and domestic markets do not change in the long run and that the export and domestic markets are not perfectly homogeneous. Cases B and C are 'in between', chosen arbitrarily for sensitivity tests, and may be looked upon as assuming different long-run

sumptions about foreign demand in the long run. See discussion later in the text.

[16] In the author's original dissertation work, the method of estimating welfare losses and transfers differs slightly from what follows and the average is taken over a shorter period.

[17] According to Dan Usher's estimate, cited in Ingram, p. 248, n. 44, the removal of the export premium when it averaged 30.0% of the export price would cause the world price to decline by 2.7%.

Table 5. Long-Run Welfare and Transfer Effects of the Export Premium 1961–70 average, in million baht

Cases	Rise in export price as % of premium (μ)	Welfare effects: Production loss	Welfare effects: Consumption cost	Transfers: From foreigners	Transfers: From farmers	Changes in foreign exchange earnings	Net loss for Thailand[a]
		1961–70 average in million baht[a]					
		(1)	(2)	(3)	(4)	(5)	(6)
A	5%	908.9	363.5	44.7	5239.3	−8020.9	1227.7
B	15%	727.6	291.0	134.2	4602.2	−6842.7	884.4
C	25%	566.5	226.5	223.7	3985.2	−5721.0	569.3
D	—[b]	99.5	39.8	462.3	2302.6	−1005.2	−323.0

Note: The average exchange rate for 1961–70 is 20.88 baht per U.S. dollar.

[a] Column (6) = Column (1) + Column (2) − Column (3).

[b] Using changes in prices and quantities predicted by the total multipliers in table 4.

elasticities of foreign demand associated with different degrees of trade liberalization and different extents to which the present institutional arrangements and buyer-seller relationships would be modified in the future.

The welfare effects and transfers of cases A, B, and C of table 5 are estimated in the following manner. First, the export premium (T) over the period 1961–70 is divided between a rise in the export price (ΔP_w) and a fall in the export price net of export premium (ΔP_e) according to the assumed value of μ. Next, assuming marketing margins are constant and that the government eliminates all other interventions on the rice economy, one would expect the domestic price to change eventually by the same amount as the export price net of export premium (or $\Delta P_d = \Delta P_e$). The long-run changes in the quantities produced and consumed, ΔQ and ΔC, are then predicted using our estimates of the slope coefficients of the domestic supply and demand curves and the adjustment coefficients from table 1. Formulas (7) to (11) are then applied to compute the various welfare and transfer effects.[18] It can be seen that in cases A to C, the net losses from imposing the export premium at the levels of the 1960s are positive and fairly large. Under the free-trade assumption (case A), for example, the net welfare loss amounts to 1.8% of national income. The transfer effect is even stronger and the loss in producer surplus of the farmer is as high as 7.8% of national income, although a large part of this loss is in an imputed sense only, since rice grown by farmers for their own subsistence is not affected by the premium. The large welfare losses computed are partly due to our assumptions that the export and domestic markets are perfectly integrated and that marketing margins are constant, so that $\Delta P_d = \Delta P_e$. If the two markets are less than homogeneous or marketing margins rise when the export premium is removed, the welfare losses in columns (1) and (2) would have been overestimated relative to the transfer from foreigners[19] and the net loss in column (6) has to be scaled down considerably.

In contrast, the export premium results in a positive net gain for Thailand in case D, in which we assume that the present characteristics of the rice trade do not change in the long run. This is because if the export premium is removed, increases in outputs would be thrown continuously into the international market, which, under the existing restrictive arrangements, would result in substantial falls in export prices and actually reduce welfare.

In all four cases, the loss in foreign exchange earnings, shown in column (5), is quite large.[20] Though not looked upon as a social cost, this may cause balance-of-payment difficulties in the future, because the deficit in Thailand's merchandise trade balance has tended to widen, and factors which have been responsible for increasing receipts in the services account and rising inflows of capital and transfers may soon disappear.

Summary and Conclusions

In the postwar period, Thailand has been in the rather peculiar position of being one of the world's largest rice exporters but not among the largest producers. While under free trade Thailand could not be expected to have any appreciable influence on world prices, it does face a downward sloping foreign demand curve under the existing conditions in the international market. In the two decades under our study, the export premium has been the most important instrument of government intervention on the rice economy. Because it constitutes a heavy tax on rice exports, and because of the importance of rice in the Thai economy, its welfare and transfer effects are substantial. During the period 1961 to 1970, the export premium has been about one-third of the export price. This is probably higher

[18] Since the export premium and export price data used in fitting the model are for white rice 5% brokens, a relatively high grade, and since in computing welfare losses and transfers it is more appropriate to use average prices and export premium rates for all grades, after applying formulas (7) to (11), the estimates are scaled down by a factor of 0.6685 which is the ratio of the average export premium for all grades of rice to the export premium for white rice 5% brokens over the period 1961–70. The average export premium for all grades is estimated by dividing total export premium revenue by the volume of rice export.

[19] This overestimation comes from two sources. First, if marketing margins increase when the export premium is removed, the increase in price to the farmer and the consumer is smaller. Second, because the change in the domestic price is smaller, the predicted changes in production and consumption (ΔQ and ΔC) based on our estimates of the slope coefficients of the supply and demand curves are also smaller.

[20] Since export prices have been converted from foreign currency units into baht using the market exchange rate, foreign exchange earnings have implicitly been valued at that rate. After the abolition of the multiple exchange rate system in 1955, the official and free-market exchange rates came together. The government has intervened only marginally in the foreign exchange market through an Exchange Equalization Fund for purposes of short-term stabilization, and it does not appear that the baht has been significantly undervalued or overvalued during the period of our welfare analysis.

than could be justified by the optimum export tax argument,[21] but it is likely that it has generated a net gain in welfare for Thailand over the period as a whole. The extent to which Thailand could continue to manipulate the international price depends on the future characteristics of the international market, over which, unfortunately, Thailand could have little control. The failure of Thailand to modify its policy in the event of drastic changes in international trading arrangements could entail very high welfare losses, as the sensitivity tests in our welfare analysis show.

In this paper only the static welfare effects of the export premium have been considered. However, the dynamic effects of the premium on the rice-producing sector should not be forgotten. The rice premium represents a substantial burden on the poor farmers. Objections on equity grounds aside, it is quite possible that the export premium, by keeping the domestic price of rice low, may lower the farmer's incentive to improve yield by adopting modern inputs (fertilizers, high-yielding varieties of rice) in paddy production, thus shifting to a higher production function. It is perhaps because of this that the paddy yield in Thailand is low when compared with most other countries, and that recently the increase in rice production in Thailand has barely kept pace with its rapid population growth (Welsch). If this is so, this loss in potential agricultural output (or unexploited potential cost reduction) has to be regarded as an additional loss. Further research into this possibility is clearly worthwhile. The export premium may result in a static welfare gain, but it may be more difficult to justify when the above mentioned dynamic effects are taken into consideration.

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[21] Neglecting the difference between short run and long run, the well known formula for the optimal rate of export tax is $\frac{1}{\eta_f}$, where η_f is the foreign elasticity of demand for Thai rice. Because η_f is estimated to be about four, the optimum export tax would be about one-fourth of the gross export price.

Welfare Implications of Grain Price Stabilization: Some Empirical Evidence for the United States

Panos A. Konandreas and Andrew Schmitz

This empirical study demonstrates that, although United States producers and consumers taken together benefit from policies which would stabilize feed grain prices, this is likely not the case for wheat. The model specifies a U.S. domestic demand relationship for food and feed use, a stock relationship and a foreign demand sector; these are estimated by ordinary and two-stage least squares methods. The key to the analysis is in testing a well-known theoretical model in which the desirability of price stabilization largely depends on the source of instability (i.e., whether instability is generated abroad or is created internally).

Key words: grain trade, price stabilization, welfare consequences for exporter.

One of the main issues facing agricultural policy-makers in recent years is price instability. Since 1972, the unprecedented increase in price instability of primary traded commodities provided the impetus for considerable worldwide concern; and, consequently, several recommendations have been made to establish commodity reserves aimed at price stabilization and security of supplies. Since the gains and losses from price stabilization are crucially dependent on the source and magnitude of the instability (Hueth and Schmitz), the welfare consequences from price stabilization for an individual country can only be ultimately determined in an empirical framework. Unfortunately, the needed empirical analysis has not been carried out. The benefits and costs of a stabilization policy have to be identified and evaluated, and the condition that makes price stabilization desirable should be derived and tested.

The objectives of this paper are, first, to derive a testable condition for the desirability of price stabilization from the point of view of an exporting country, and then to specify and estimate a trade model for each of the major grain commodities exported by the United States and to test the condition derived above.

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Welfare Considerations of Price Stabilization

Hueth and Schmitz extended the closed-economy framework, advanced by Waugh, Oi, and Massell, to examine internationally traded goods. Their results show that whether or not an individual country benefits from price stability depends critically on the source of the instability. First, when the source of instability originates in only one of the two countries considered, that country will always prefer stabilized prices if domestic compensation is paid. However, price instability is preferable for the country that does not contribute to instability. Moreover, in this latter case domestic compensation is not necessary, making price instability Pareto superior. Second, if both countries contribute to price instability, the results, with respect to which country gains from price stabilization, are inconclusive on theoretical grounds. However, within each country, price stabilization is undesirable for the group that does not contribute to instability. Finally, regardless of the source or the extent of the instability when international compensation is paid, price stabilization is a desirable policy for both world consumers and producers. That is, the

group that benefits from price stabilization is able to compensate both domestic and foreign losers and still be better off.

The theoretical analysis dealt with in this paper applies to a grain exporting country, such as the United States or Canada, facing stochastic shifts in both domestic grain production and in their export demand (due to production fluctuations in the rest of the world). In this case, as noted earlier, the theoretical conclusions of Hueth and Schmitz are inconclusive. A simplifying assumption made here is that the domestic demand functions are nonstochastic. The demand for several agricultural commodities, and grains in particular, is highly price and income inelastic; thus, the above assumption can be justified. In addition, it appears that instability in prices due to fluctuations in supply caused by such factors as weather are much greater relative to those brought about by demand changes (except for such factors as income growth which, *ceteris paribus*, should not cause instability).

Let demand and supply in the exporting country be represented by

$$(1) \qquad D_t = a_0 + a_1 Z_{dt} - a_2 P_t,$$

$$(2) \qquad S_t = b_0 + b_1 Z_{st-1} + b_2 P^*_t + U_{qt} = Q_t + U_{qt},$$

and demand and supply in the rest of the world by

$$(3) \qquad D'_t = a'_0 + a'_1 Z'_{dt} - a'_2 P'_t,$$

$$(4) \qquad S'_t = b'_0 + b'_1 Z'_{st-1} + b'_2 P'^*_t + U'_{qt} = Q'_t + U'_{qt},$$

where Z_{dt}, Z_{st-1} and Z'_{dt}, Z'_{st-1} are factors other than price affecting demand and supply, P_t and P'_t are prices of the commodity in year t, P^*_t and P'^*_t are producers' expected prices in year t, and U_{qt} and U'_{qt} are production fluctuations in year t. Next, U_{qt} is assumed independent of U'_{qt} with expected value and variance, $E(U_{qt}) = E(U'_{qt}) = 0$, and

$$V(U_{qt}) = \sigma_q^2, \text{ and } V(U'_{qt}) = \sigma'^2_q.$$

The components Q_t and Q'_t in equations (2) and (4) represent expected output in year t based on producers' decisions in year $t - 1$, assuming that production is free of stochastic components.

Equilibrium between the two markets is obtained by equalization of the excess supply with the excess demand in conjunction with a transportation cost relationship, i.e., $S_t - D_t = D'_t - S'_t$, and $P'_t = P_t + T_t$, where T_t denotes the cost of transporting the commodity between the exporting country and the rest of the world. The equilibrium price obtained after substitution is

$$(5) \qquad P_t = \frac{a_0 + a'_0 + a_1 Z_{dt} + a'_1 Z'_{dt} - a'_2 T_t - Q_t - Q'_t}{a_2 + a'_2}, - \frac{1}{a_2 + a'_2} U_{qt} - \frac{1}{a_2 + a'_2} U'_{qt},$$

or

$$(6) \qquad P_t = P_{ot} + \frac{\partial P_t}{\partial Q_t} U_{qt} + \frac{\partial P_t}{\partial Q'_t} U'_{qt},$$

with expected value and variance as

$$(7) \qquad E(P_t) = P_{ot},$$

and

$$(8) \qquad V(P_t) = \left(\frac{\partial P_t}{\partial Q_t} \sigma_q\right)^2 + \left(\frac{\partial P_t}{\partial Q'_t} \sigma'_q\right)^2, = V_d(P_t) + V_f(P_t),$$

where P_{ot} is equal to the first term of the right-hand side of equation (5) and represents the price that would prevail in the exporting country in the absence of stochastic fluctuations in domestic and foreign supplies. The first term of equation (8) is the component of the variance in price due to fluctuations in domestic production, and the second term is due to fluctuations in foreign production.

If price in the exporting country at year t is maintained at the P_{ot} level, through the operation of a costless buffer stock, for example, then the gains to domestic producers, consumers, and the country as a whole are

$$(9) \qquad G_t^p = P_{ot} S_t - P_t S_t,$$

$$(10) \qquad G_t^c = \tfrac{1}{2} (P_t - P_{ot})(D_t + D_{ot}),$$

and

$$(11) \qquad G_t = G_t^p + G_t^c,$$

where D_t and D_{ot} represent the domestic demand schedule evaluated at P_t and P_{ot}, respectively.

After substitution and taking expectations, the above expressions become:

$$(12) \qquad E(G_t^p) = - \frac{\partial P_t}{\partial Q_t} \sigma_q^2,$$

$$(13)\quad E(G_t^c) = \frac{1}{2}\left\{\left(\frac{\partial P_t}{\partial Q_t}\sigma_q\right)^2 + \left(\frac{\partial P_t}{\partial Q'_t}\sigma'_q\right)^2\right\}\Big/\frac{\partial P_t}{\partial D_t},$$

and

$$(14)\quad E(G_t) = -\frac{\partial P_t}{\partial Q_t}\sigma_q^2 + \frac{1}{2}\left\{\left(\frac{\partial P_t}{\partial Q_t}\sigma_q\right)^2 + \left(\frac{\partial P_t}{\partial Q'_t}\sigma'_q\right)^2\right\}\Big/\frac{\partial P_t}{\partial D_t}.$$

Net expected welfare gains as given by equation (14) are positive when

$$(15)\quad \frac{1}{2}\frac{\partial P_t/\partial Q_t}{\partial P_t/\partial D_t} < \frac{\left(\frac{\partial P_t}{\partial Q_t}\sigma_q\right)^2}{\left(\frac{\partial P_t}{\partial Q_t}\sigma_q\right)^2 + \left(\frac{\partial P_t}{\partial Q'_t}\sigma'_q\right)^2},$$

or

$$(16)\quad \frac{1}{2}\frac{\partial P_t/\partial Q_t}{\partial P_t/\partial D_t} < \frac{V_d(P_t)}{V_d(P_t) + V_f(P_t)}.$$

If the above condition holds, then price stabilization at P_{ot} during year t is desirable from the point of view of both domestic consumers and producers in the exporting country. It should be noted, however, that domestic compensation is required in this case for price stabilization to be preferable. It follows from equation (13) that gains to domestic consumers are negative. However, gains to domestic producers, equation (12), are positive; and, should the above condition hold, these gains exceed consumer losses. Therefore, in this latter case, domestic producers can compensate domestic consumers and still be better off with price stability than price instability.

Model Specification

This section specifies an econometric model for each of the major grains produced and traded by the United States (wheat, oats, maize, barley, and sorghum). The model consists of a domestic demand relationship for the amount consumed domestically in either food, feed, or seed form; a stock relationship for the amount carried from year to year by the government and commercial agents; and a foreign demand relationship describing U.S. commercial exports. Finally, an identity of quantity flows equates total supply for a particular year with total demand.

Domestic Demand

Specification of a demand function suitable for statistical estimation is governed by principles of price theory and by the peculiarity of the commodity and the environment under consideration. For estimation, price has been chosen as the dependent variable (see Fox, chap. 2, and Tweeten). The short-run price relationship for the ith grain is specified as follows

$$(17)\quad P_{it} = f_i^p\ (P_{it-1}, D_{it}, Y_t, PT_{it}, T, u_{it}^p),$$

where D_{it} is domestic consumption (in all forms), P_{it} is domestic wholesale price, PT_{it} is domestic wholesale price of another grain commodity substitute in consumption, Y_t is per capita income, T is a time trend, and u_{it}^p is random disturbance.

Domestic Stocks

Quantities of grain accumulated by commercial agents are mainly determined by the current market price. The higher the current market price, the more commercial stocks are reduced and the less the incentive to acquire new grain and vice versa. The assumption made here is that commercial agents' expectations on next year's prices are optimistic when current prices are low and pessimistic when current prices are high.

Under the government price-support program, a portion of the grain produced during a particular year was delivered by producers to the Commodity Credit Corporation (CCC). A farmer was able to obtain a loan from the CCC using his grain as collateral and repay his loan by delivering grain or cash to the CCC at some future date. The alternative given to farmers of repaying their loans in cash was to their advantage when the market price exceeded the support price for a particular year. Thus, the higher the market price and the lower the support price, the less the amount of grain delivered to the CCC. The CCC also agreed to buy all the grain delivered by farmers at the preset support price, subject to the condition that the individual farmer did not exceed his acreage allotment or whatever other quantitative restrictions were in effect. This implies that the higher the grain production for a particular year, other things being equal, the higher the ending stocks. Another factor affecting stocks was the magnitude of concessional exports. Since 1954, considerable quan-

tities of grain have been exported from the United States under P. L. 480 and, other factors being equal, the higher their volume for a particular year, the lower the ending stocks. A final consideration deals with grain accumulated during previous periods.

A functional form for the ith grain, which takes into account the above, is

$$(18)\quad S_{it} = f_{it}^{s}\,(S_{it-1}, Q_{it}, PS_{it}, P_{it}, C_{it}, u_{it}^{s}),$$

where S_{it} is stock level held by both the CCC and commercial agents at the end of the year, Q_{it} is current production, PS_{it} is support price, C_{it} is concessional exports, under P. L. 480, and u_{it}^{s} is random disturbance.

Foreign Demand

Specification of an estimable foreign demand relationship involves, on the one hand, aggregation of variables entering the import demand function of each importing country and, on the other hand, aggregation of importing countries. With respect to the first, monetary variables affecting import demand from the United States by the kth country, namely, U.S. export price (p^{us}), domestic per capita income of the kth country (Y^k), and exchange rate between the United States and the country in question (ER^k), have been combined into two variables:

$$\frac{p^{us}}{p^k/ER^k} \text{ and } \frac{Y^k}{ER^k}.$$

This specification, first, reflects the suggestion made in the literature for expressing monetary variables into a common currency (see, for example, Bjarnason, McGarry, Schmitz) and, second, avoids problems of estimation due to a high degree of multicollinearity among monetary variables should they be included individually.

Importing countries have been aggregated into five regions based on geographical, economic, and political characteristics. These regions are developed countries (including Japan, Israel, and South Africa); Latin America, Asia (excluding Communist Asia, Japan, and Israel); Africa (excluding South Africa); and the USSR and Eastern Europe.

Total foreign demand for the ith U.S. grain by the rest of the world (all five regions specified above) is postulated as

$$(19)\quad X_{it} = f_i^{x}\,(X_{it-1}, SXC_{it}, Q'_{it}, C_{it}, PE_{it}, YE_{i1t}, YE_{i2t}, YE_{i3t}, YE_{i4t}, YE_{i5t}, u_{it}^{x}),$$

where X_{it} is the total quantity exported by the United States, SXC_{it} is stock level held by U.S. export competitors in the beginning of year t, expressed in per capita (excluding the United States), Q'_{it} is per capita world production (excluding the United States), and

$$PE_{it} = \sum_{j=1}^{5}\left\{w_{ij}\sum_{k=1}^{K_j} w_{ij}^{k}\,\frac{p_{it}^{us}}{p_{ijt}^{k}/ER_{jt}^{k}}\right\}$$

is the effective U.S. export price, w_{ij} is average share of the jth region's imports from the United States for the three years preceding t, w_{ij}^{k} is average share of the kth country's imports from the United States (within the imports of the jth region) for the three years preceding t, K_j is number of major importers of U.S. grain within the jth region, p_{it}^{us} is U.S. export price, p_{ijt}^{k} is domestic price in the kth country of the jth region, Y_{jt}^{k} is per capita real income in the kth country of the jth region, ER_{jt}^{k} is exchange rate (foreign currency per U.S. dollar) of the kth country of the jth region,

$$YE_{ijt} \text{ is } \sum_{k=1}^{K_j} w_{ij}^{k}\,\frac{Y_{jt}^{k}}{ER_{jt}^{k}}$$

is effective per capita real income of the K_j countries of the jth region weighted by their import shares for the ith U.S. grain, and u_{it}^{x} is random disturbance.

A final consideration in the specification of the model deals with an accounting of quantity flows. Total supply for the ith grain should equal total disappearance. This implies the following identity:

$$(20)\quad D_{it} = Q_{it} + I_{it} + S_{it-1} - S_{it} - X_{it} - C_{it},$$

where I_{it} equals U.S. imports, and the remaining variables are as defined previously.

Estimation

Estimated domestic price and stock relationships are presented in tables 1 and 2, respectively. Two procedures were used in the estimation. First, ordinary least squares (OLS) is applied to each equation (17) and (18) separately. Second, the system of equations (17)

Table 1. Estimates of U.S. Grain Price Relationships (1955–1972)

Dependent Variable (P_{it})		Constant	Lagged Price (P_{it-1})	Consumption (D_{it})	Income (Y_t)	Price of Substitutes[a] (PT_{it})	Time Trend (T)	General Statistics D.F.	R^2
Wheat	OLS	89.53	0.009	−0.00165	−0.0027	0.132	−1.252	12	.88
		(5.15)[b]	(0.283)	(0.00150)	(0.0123)	(0.104)	(1.062)		
	TSLS	67.51	0.117	−0.000147	−0.0078	0.123	−0.756	12	
		(5.28)	(0.270)	(0.000227)	(0.0093)	(0.106)	(0.921)		
Oats	OLS	74.61	−0.288	−0.0015	0.00757	0.209	−1.90	12	.75
		(2.86)	(0.208)	(0.0008)	(0.00676)	(0.096)	(1.07)		
	TSLS	81.70	−0.318	−0.0018	0.00917	0.195	−2.21	12	
		(2.75)	(0.201)	(0.0007)	(0.00662)	(0.093)	(1.06)		
Maize	OLS	−1.40	0.059	0.00016	0.000055	0.483	−0.358	12	.84
		(3.34)	(0.222)	(0.00017)	(0.006714)	(0.120)	(0.802)		
	TSLS	9.61	0.046	−0.0000355	0.00173	0.476	−0.088	12	
		(3.43)	(0.023)	(0.0002150)	(0.00702)	(0.124)	(0.840)		
Barley	OLS	73.74	−0.239	−0.00303	−0.00561	0.289	0.392	12	.81
		(3.04)	(0.220)	(0.00169)	(0.00598)	(0.115)	(0.637)		
	TSLS	95.58	−0.373	−0.0048	−0.0024	0.226	0.144	12	
		(2.90)	(0.234)	(0.0021)	(0.0062)	(0.120)	(0.637)		
Sorghum	OLS	0.99	0.177	−0.00113	0.00328	1.288	0.444	12	.88
		(4.95)	(0.192)	(0.00153)	(0.00991)	(0.265)	(1.662)		
	TSLS	0.29	0.076	−0.00258	0.00333	1.50	1.52	12	
		(4.59)	(0.181)	(0.00148)	(0.00920)	(0.27)	(1.55)		

Note: For footnotes, see the end of table 2.

Table 2. Estimates of U.S. Ending Grain Stock Relationships (1955–1972)

Dependent Variable (S_{it})		Constant	Lagged Stocks (S_{it-1})	Current Production (Q_{it})	Support Price (PS_{it})	Wholesale Price (P_{it})	Concessional Exports (C_{it})	General Statistics D.F.	R^2
Wheat	OLS	−8522.9	0.982	0.725	338.6	−409.3	−1.07	12	.87
		(3380.1)[b]	(0.161)	(0.307)	(146.0)	(299.1)	(0.35)		
	TSLS	−18838.9	0.920	0.882	463.7	−441.1	−1.05	12	
		(3116.4)	(0.154)	(0.303)	(159.6)	(276.6)	(0.32)		
Oats	OLS	2872.5	1.00	0.0807	84.0	−157.5	[c]	13	.74
		(745.1)	(0.17)	(0.0612)	(47.0)	(48.0)			
	TSLS	4181.0	1.07	0.102	152.5	−260.0	[c]	13	
		(589.7)	(0.14)	(0.049)	(43.2)	(50.3)			
Maize	OLS	159115.0	−0.112	−0.0458	−689.7	−1219.7	[d]	13	.91
		(3803.0)	(0.172)	(0.0568)	(301.6)	(199.0)			
	TSLS	171358.0	−0.175	−0.0601	−701.3	−1360.0	[d]	13	
		(4047.1)	(0.190)	(0.0617)	(321.1)	(243.1)			
Barley	OLS	−454.6	0.242	0.4128	67.1	−69.0	[d]	13	.80
		(492.7)	(0.160)	(0.1537)	(33.7)	(39.2)			
	TSLS	4022.5	0.164	0.2613	91.0	−143.1	[d]	13	
		(429.0)	(0.143)	(0.1490)	(31.1)	(47.2)			
Sorghum	OLS	35530.8	0.580	−0.1626	141.1	−418.4	−1.69	12	.96
		(1333.6)	(0.067)	(0.1190)	(150.5)	(107.8)	(0.63)		
	TSLS	39603.0	0.549	−0.2461	259.4	−516.7	−1.47	12	
		(1246.6)	(0.065)	(0.1230)	(159.6)	(118.6)	(0.60)		

Note: Data sources used are as follows: P_{it} were obtained from (c) and (f); PT_{it} from (c) and (d); PS_{it} from (b); Y_t from (i); S_{it} from (b), (c), (e), and (f); Q_{it} from (b) and (e); C_{it} from (g); I_{it} from (e) and (h); and X_{it} from (a) and (g); *where*: (a) FAO, *World Grain Trade Statistics*; (b) USDA, *Agricultural Statistics*; (c) USDA, *Feed Situation*; (d) USDA, *Rice Situation*; (e) USDA, *Grain Production, Consumption, Stocks, and Trade* (Computer reprint 3/10/75); (f) USDA, *Wheat Situation*; (g) USDA, *U.S. Agricultural Exports Under Public Law 480*; (h) USDA, *World Grain Trade Statistics*; and (i) USDA, *Statistical Abstracts*.

[a] Substituting commodity for each grain was determined after extensive experimentation with several alternatives. Only the price of the commodity that had the proper sign and was the most statistically significant was included in the final regressions. Thus, for wheat the most statistically significant substitute commodity turned out to be rice; for oats, maize; and barley, it was sorghum; and, finally, for sorghum it was maize.

[b] Numbers in parentheses represent estimated standard errors.

[c] Oats have not been exported by the U.S. under concessional terms.

[d] Preliminary estimations yielded incorrect sign and insignificance; thus, variables were omitted from final estimation.

and (18) together with identity (20) is estimated by a two-stage least squares (TSLS) procedure.

The coefficients of the lagged price variable in the estimated price relationships turned out to be within the expected range (0 to 1) for one-half of the cases. The magnitudes of these coefficients are very close to zero in absolute value, and in none of the cases are they significantly different from zero. This indicates that the adjustment of prices to current changes in the exogenous variables is quite rapid. The coefficients of domestic consumption are all negative as expected except for maize where the coefficient was positive but insignificant. Domestic income has a positive effect on prices except for wheat and barley. Although in both of these cases the coefficients are not significant, the negative income coefficient in the case of wheat is anticipated (see other evidence by Rojko, Urban, Naive, p. 35). The coefficients of the price of substituting commodities are all positive as expected. Finally, most of the coefficients of the trend variable are negative, which reflects a generally downward trend in grain prices during the period of analysis.

With respect to estimated stock relationships, the coefficients of the lagged stock variable are all positive as anticipated except in the case of maize; however, this negative coefficient is not significantly different from zero. The effects of current production on stocks are positive except in the cases of maize and sorghum. An explanation of the negative effects in the latter two cases might be found in the high demand, both domestic and foreign, for these commodities due to increased consumption of livestock products which absorbed most of the increase in domestic production. Support prices have a positive effect on stocks for all commodities except maize. Possible causes of this latter case could be of the same nature as those of the current production coefficient. The coefficients of the wholesale price variable are all negative as anticipated. Finally, concessional sales affect stocks negatively, again in agreement with a priori expectations.

Extraneous information is employed in the estimation of foreign demand of U.S. grain. Income elasticities of total demand for grain commodities have been reported in the literature either on a country-by-country basis or a regional basis (this study employs estimates of Rojko, Urban, Naive). Income elasticities of import demand can be obtained from income elasticities of total demand which, in turn, can be translated into income coefficients and, consequently, be used as extraneous information in the estimation of foreign demand of U.S. grain. Estimation with extraneous information, as applied here, assumed that income elasticities are known with certainty.[1]

OLS estimates of U.S. foreign demand for grains are presented in table 3. The coefficients of lagged exports are in the range between 0 and 1. This is the case for all except one commodity, wheat. Elimination of lagged exports in this latter case (due to its statistical insignificance) did not affect the explanatory power of the estimated equation. The coefficients of effective U.S. export price and per capita world production are all negative as anticipated.[2] Stocks of export competitors affect U.S. exports negatively except in the case of barley. Elimination of this variable in the case of barley (due to its statistical insignificance) reduced the explanatory power of the equation very slightly—R^2 dropped from 0.50 to 0.48. Finally, the coefficients of concessional U.S. exports on commercial exports are negative, except in the case of sorghum. In particular, for each additional 1,000 metric tons of concessional wheat exports (maize and barley), commercial exports drop by 141 metric tons (624 and 238, respectively). The case of sorghum seems to be the opposite; that is, concessional exports resulted in the establishment of commercial channels in the rate of 493 metric tons for each 1,000 metric tons exported under P. L. 480. These results are not totally conclusive due to the high standard errors of the estimated coefficients; however, they are in line with the conclusion reached by Abbott that, in general, P. L. 480 food aid has been a substitute for commercial imports by recipient countries rather than an addition to commercial imports.

The Test

Test of the condition of the desirability of price stabilization, as expressed by inequality

[1] A detailed computation of income coefficients associated with regional income variables, given extraneous estimates of income elasticities, can be found in Konandreas. Theil and Goldberger suggest a mixed estimation procedure which takes into consideration the uncertainty related with the extraneous information. However, variances of the extraneous estimates of income elasticities were not available; thus, mixed estimation is not applicable here.

[2] The corresponding price elasticities, i.e., $(\partial X/\partial P)\ (\bar{P}/\bar{X})$, for wheat are −3.13 and −2.95; oats, −0.89; maize, −1.28; barley, −0.27 and −0.75; and sorghum, −3.04.

Table 3. Estimates of Foreign Demand for U.S. Grain (1955-1972)

Dependent Variable (X_{it})	Constant	Lagged Dependent (X_{it-1})	Effective US Export Price (PE_{it})	Stocks of Export Competitors[a] (per Capita) (SXC_{it})	World Production[b] (per Capita) (Q'_{it})	Concessional US Exports (C_{it})	Per Capita Income of Importing Regions[c] YE_{Jit}	YE_{Eit}	YE_{Cit}	YE_{Hit}	YE_{Rit}	General Statistics D.F.	R^2
Wheat	48991.6	−0.090	−368.1	−343.2	−99.2	−0.176	−7.959	12.12	8.21	5.7279	0.1325	12	.63
	(2258.0)[d]	(0.298)	(122.9)	(375.9)	(99.1)	(0.235)							
	47052.6	[e]	−346.8	−298.1	−103.2	−0.141	−7.959	12.12	8.21	5.7279	0.1325	13	.63
	(2177.7)		(97.4)	(332.8)	(94.6)	(0.197)							
Oats	1374.2	0.1877	−3.8	−44.6	−15.9	[f]	8.133	0.16	0.00087	[g]	[g]	13	.45
	(155.7)	(0.2225)	(5.0)	(127.7)	(7.7)								
Maize	16506.4	0.5487	−227.4	−1100.0	−58.4	−0.6235	64.102	6.80	0.0415	0.1265	0.1466	12	.88
	(1865.0)	(0.1872)	(113.4)	(1171.1)	(104.8)	(1.0919)							
Barley	3249.3	0.2117	−4.2	268.7	−51.0	−0.357	26.787	0.78	0.1594	[g]	0.1053	9	.50
	(485.3)	(0.2927)	(34.3)	(420.1)	(25.6)	(0.395)							
	4627.3	0.1187	−11.4	[e]	−56.0	−0.238	26.787	0.78	0.1594	[g]	0.1053	10	.48
	(470.8)	(0.2464)	(31.4)		(23.7)	(0.338)							
Sorghum	11653.3	0.3977	−156.4	−71.3	−64.8	0.493	26.879	0.60	0.2881	0.1437	0.0030	12	.68
	(776.8)	(0.3091)	(78.8)	(1270.0)	(52.2)	(0.465)							

Note: Data sources for X_{it} and C_{it} are given in tables 1 and 2. SXC_{it} were obtained from (b), (c), (e), (f), and (l), and Q'_{it} from (k), (m), and (l). PE_{it} and YE_{it} were computed according to the expressions provided in the text with: w_{it} and w_{it}^{k} computed from (a); ER_{t}^{k} obtained from (j); and P_{it}^{us} computed as the ratio between value of exports over quantity exported both obtained from (n). Since domestic grain prices in the importing countries (P_{it}^{k}) were not available consistently, a proxy variable, food price index (1958 = 100) obtained from (1), was used instead in the expression of PE_{it}. This indexing in domestic prices required also indexing of exchange rates. Thus, exchange rates entered the expression of PE_{it} in the form of a ratio between the current exchange rate (ER_{t}^{k}) and the exchange rate of the base period (ER_{1958}^{k}). Similarly, income time series for the importing countries (Y_{t}^{k}) were not available consistently in absolute terms; income time series in an index form (1958 = 100) were used instead, obtained from (1). Again the expression for YE_{it} was corrected to incorporate exchange rates in the form of a ratio. *Where*: data sources (a) through (i) are given in tables 1 and 2; (j) IMF, *International Financial Statistics*; (k) FAO, *Production Yearbook*; (l) UN, *Statistical Yearbook*; (m) FAO, *World Crop Statistics: Area, Production, and Yield, 1948–64*; and (n) USDA, *Foreign Agricultural Trade of the U.S.*

[a] U.S. export competitors considered include: for wheat, oats, and barley: Canada, Argentina, and Australia; for maize: Argentina and South Africa; and for sorghum: Argentina.

[b] Grain production (per capita) of the rest of the world was computed on a foodgrain/feedgrain basis. In the case of wheat, the variable entering constitutes the sum of wheat, rice, and rye world production during a particular year divided by world population during the same year. Similarly, in the case of one of the feedgrains, per capita world production includes all feedgrains produced; namely, the sum of oats, maize, barley, and sorghum, divided by world population. U.S. grain production and population are excluded from the above computations.

[c] The coefficients of the income variables were not estimated but extraneously introduced. The consistency of the extraneous information with the sample data was tested in the estimation of a disaggregated model involving U.S. exports to each region individually. The X^2 test was affirmative in all cases.

[d] Numbers in parentheses represent estimated standard errors.

[e] Due to an incorrect sign and insignificance, the respective variable is dropped from the final specification.

[f] Oats have not been exported by the U.S. under concessional terms.

[g] The respective region does not import from the U.S.

(16), requires the construction and estimation of an appropriate measure of production variability over time. This would have been possible if domestic and foreign supply responses in the forms of specifications (2) and (4) had been estimated. However, supply responses were not estimated in this study, but instead both current domestic and foreign production were exogenous to the model.

As an alternative to explicitly estimating supply responses in order to measure the fluctuation in grain production, it is assumed that the individual variables affecting supply—such as prices, technology, population growth, etc.—are reflected in the growth of output over time. Thus, the time trend of output growth will be assumed to reflect the nonstochastic components of supply response; therefore, the purely stochastic fluctuation in output will be measured as the year-to-year deviation of actual production from its time trend. This alternative suggests regressing actual grain output, both domestic and foreign, against time.[3] The "unexplained" variation with respect to time would then serve as a measure of supply variability. The standard deviation of the differences between actual and trend production is reported in table 4, column 3 (line designated by A) and column 6 (line designated by C) for domestic production and foreign per capita production, respectively.

Acreage controls were in effect in the United States for most grains during the period of the analysis. This implies that the deviation of grain production from its trend for a particular year includes a purely stochastic component reflected in crop yields and a deterministic (intended) component, acreage allotments, which represents a conscious governmental policy. Therefore, part of the year-to-year fluctuation in domestic grain production is policy induced. Thus, the corresponding fluctuation in domestic prices can be con-

[3] A linear time trend of output growth was estimated.

sidered as anticipated and, consequently, desirable. The remainder of the variability in domestic production is due to fluctuations in yields alone. Symbolically, this can be stated as

$$Q_t = a_t y_t = a_t(y_{ot} + \Delta y_t) = a_t y_{ot} + a_t \Delta y_t,$$

where Q_t, a_t, and y_t represent actual production, acreage, and yield, respectively, and y_{ot} is expected (trend) yield. Thus, $a_t y_{ot}$ is the anticipated production during year t which deviates from actual production by $a_t \Delta yt$.

The above suggests an alternative measure of domestic production variability, which is expected to be smaller than the one derived previously since fluctuations in yields only are considered. The additional assumption needed for this to be true is that acreage control policy during year t, which is reflected in the production of year $t + 1$, and yields of year $t + 1$ are two independent events. The standard deviations of the yield-induced deviations in production (computed as the year-to-year deviations in yields multiplied by actual acreage) are reported in table 4, column 3 (lines designated by B).

Fluctuations in foreign production affect domestic U.S. price through the export demand relationship (the system of equations (17), (18), (19), and (20) is solved for its reduced form). However, the fit of the estimated export demand relationships (table 3) is rather poor; and, in addition, the estimated coefficients have high standard errors. Therefore, part of the impact of foreign production on domestic prices is lost when the estimated export demand is introduced into the system (i.e., when exports are treated as an endogenous variable). As an alternative to this difficulty, one could treat exports as an exogenous variable [the system then consists of equations (17), (18), and (20)]. Under this framework, a change in exports (rather than foreign production) is reflected directly in a change in domestic prices. In order to implement this alternative, the variability of the volume of exports has been computed. The standard deviation of actual exports from a time trend (σ_{xt}) is reported in table 4, column 6 (lines designated by D).

Table 4 summarizes the series of steps involved in testing the condition for the desirability of price stabilization as expressed by inequality (16). A comparison of columns 8 and 9 indicates that the condition holds conclusively for all grains and all alternatives considered except for wheat. Note that, when the variability in domestic production is measured by variability in yields and when variability in foreign production is measured by variability in export volume, the condition for wheat price stabilization is not met. However, under the other alternatives presented, the condition is met but not to the same degree as in the feed grain cases. It is clear that a slight error in econometric estimation could have reversed the results for the wheat case (e.g., 0.058 in table 4 is only slightly above 0.056).

To provide further insights into whether or not price stabilization is desirable, the relationship between export volumes expressed as percentages of total domestic production and the portion of domestic price instability induced by fluctuations in export demand is examined. The relative degree of the effect of fluctuations in foreign demand on domestic price variability is presented in column (10). Finally, the last column of table 4 represents the ratio (average over the period of consideration) between total exports of each grain and domestic production. In general, the higher the percentage of exports to total production, the higher the variability in domestic prices induced by fluctuations in export demand. For example, the 58% of U.S. wheat exported causes more than two-thirds of the total instability in the domestic price of wheat. In view of this observation, the conclusion reached earlier that the condition for the desirability of price stabilization for the wheat sector is not conclusively met should be anticipated. On purely theoretical grounds, price instability is preferable when the major source of the instability is external, and it is not preferable when the major source of the instability is internal to the country under consideration.

Conclusions and Limitations

Recently, there has been a proliferation of theoretical studies which attempt to determine the distribution of welfare gains from price stabilization. Unfortunately, many of the models developed have not been empirically tested. This paper has focused on empirical estimation of the condition which makes price stabilization desirable. Specifically, the objective of this analysis has been to test whether or not grain price stabilization is a desirable policy from the point of view of the United States where instability in the grain market is created

Table 4. Test of the Condition for the Desirability of Price Stabilization

Commodity	$\frac{\partial P_u}{\partial D_u}$ (1)	$\frac{\partial P_u}{\partial Q_u}$ (2)	(1) *domestic production due to:* A: both acreage and yields B: yields (only) — σ_{Qt} (3)	$V_d(P_t)$ (4)	(2) *foreign production through* C: estimated export demand D: export volume (directly) — $\frac{\partial P_u}{\partial Q'_u}$ or $\frac{\partial P_u}{\partial X_u}$ (5)	σ'_{Qt} or σ_{Xt} (6)	$V_f(P_t)$ (7)	Test: for the desirability of price stabilization column 9 must be greater than column 8 — $\frac{1}{2}\frac{\partial P_u/\partial Q_u}{\partial P_u/\partial D_u}$ (8)	$\frac{V_d(P_t)}{V_d(P_t)+V_f(P_t)}$ (9)	Percentage of Price Instability due to exports, and export dependency — $100\sqrt{\frac{V_f(P_t)}{V_d(P_t)+V_f(P_t)}}$ (10)	$\frac{\bar{X}_t}{\bar{Q}_t}$ (11)
Wheat	-0.147×10^{-3}	-0.0163×10^{-3}	A 3.884×10^3	0.004007	C -0.0142	7.106	0.010181	0.05544	0.28242	47	58
					D 0.138×10^{-3}	1.854×10^3	0.065434		0.05770	76	
			B 2.538×10^3	0.001714	C -0.0142	7.106	0.010181		0.14409	62	
					D 0.138×10^{-3}	1.854×10^3	0.065434		0.02553	84	
Oats	-1.800×10^{-3}	-0.8644×10^{-3}	A 1.768×10^3	2.335390	C -0.0153	5.134	0.006178	0.24011	0.99736	1	2
					D 0.963×10^{-3}	0.153×10^3	0.021697		0.99079	1	
			B 0.916×10^3	0.626947	C -0.0153	5.134	0.006178		0.99423	1	
					D 0.963×10^{-3}	0.153×10^3	0.021697		0.99655	2	
Maize	-0.036×10^{-3}	-0.0359×10^{-3}	A 8.243×10^3	0.087557	C -0.0020	5.134	0.010527	0.49861	0.89267	6	10
					D 0.034×10^{-4}	1.863×10^3	0.004007		0.95624	3	
			B 5.546×10^3	0.038377	C -0.0020	5.134	0.010527		0.78474	12	
					D 0.034×10^{-3}	1.863×10^3	0.004007		0.90546	5	
Barley	-4.800×10^{-3}	-2.1017×10^{-3}	A 1.165×10^3	5.992700	C -0.1594	5.134	0.669780	0.21893	0.89947	6	16
					D 2.845×10^{-2}	0.500×10^3	2.023506		0.74757	14	
			B 0.508×10^3	1.140600	C -0.1594	5.134	0.669780		0.63003	21	
					D 2.845×10^{-2}	0.500×10^3	2.023506		0.36048	40	
Sorghum	-2.580×10^{-3}	-1.3780×10^{-3}	A 2.573×10^3	12.574116	C -0.0716	5.134	0.135130	0.26701	0.98937	1	20
					D 1.106×10^{-3}	0.948×10^3	1.099352		0.91960	5	
			B 1.414×10^3	3.794700	C -0.0716	5.134	0.135130		0.96556	2	
					D 1.106×10^{-3}	0.948×10^3	1.099352		0.77537	13	

Columns (1)–(7) fall under the heading "Domestic Price Variability caused by fluctuations in".

Note: Computation procedures for columns (3) and (6) are indicated in the text. The source of the information in the other columns is as follows: (1) were obtained from table 1 (TSLS case); (2) and (5) are the reduced form coefficients (short-run multipliers) between domestic price and domestic and foreign production (or export volume), respectively; (4) is the product of (2) and (3) squared; and (7) is the product of (5) and (6) squared.

from both within and outside the country. It was shown that U.S. producers and consumers taken together would benefit from feed grain price stabilization. The results were inconclusive for the wheat sector; however, they tended to suggest (since storage costs were not included) that price instability is desirable.[4]

The implications of this study should be viewed with caution and interpreted within the assumptions explicitly or implicitly made and the empirical and theoretical limitations of the methodology involved. Storage costs were not considered in this analysis. Should these costs be included in the computation of total U.S. welfare gains from price stabilization, it is not clear whether or not the conclusions reached here would still hold. Recent studies by Danin, Sumner and Johnson, Reutlinger, and Sarris evaluating buffer stock levels, in terms of direct costs and benefits resulting from the operation of grain stocks, come to the conclusion that optimal buffer stocks are likely to be too low to afford satisfactory levels of price and consumption stabilization on a worldwide basis. Although adequate levels of grain stocks might not be justified from purely economic considerations, the humanitarian aspects involved cannot be overlooked. It might well be that "the use of standard theory to rationalize and determine the size of reserves is inadequate if not irrelevant . . . because it cannot measure the irreversible losses due to inadequate food supplies" (Hathaway, p. 2). However, the responsibility for guaranteeing the world adequate supplies of food and at reasonably stable prices cannot be identified with a particular nation. International cooperation in the administration of a grain reserve scheme and in the allocation of costs involved in acquiring and holding stocks among the beneficiary nations is needed in order to make the goal of feeding the world's people attainable and operational on a long-term basis. Within such a framework, the United States should be willing to fully cooperate.

In addition to the assumption of zero storage costs, the model used was based on a linear and nonstochastic demand, and the only instability assumed in the system was induced through additive fluctuation in grain production. Recent theoretical studies have considered less stringent conditions with respect to these assumptions. Specifically, Hazell and Scandizzo have introduced the notion of multiplicative production risk in a linear framework which was extended by Newbery to include nonlinearity in both supply and demand. Also, Just et al. (1977a; b, forthcoming), examined the welfare effects of price stabilization within an international trade context (both free trade and trade under distortions, respectively) under the assumption of nonlinearity in demand. Their findings show that the results depend crucially on the assumptions made with respect to the shape of the demand schedule; the origin of the disturbances; whether risk is additive or multiplicative; and, finally, on the nature of producers' behavior in terms of associated risks. However, the conclusions by Just et al. are that generally importing countries gain from price stabilization at the expense of producers in exporting countries. This result further supports the findings in this paper concerning the U.S. wheat sector.

This study examined the gains from price stabilization only for the United States. However, it is generally true that policies intended to stabilize domestic markets usually result in increased instability for the rest of the world.[5] A vivid example of such destabilizing forces is the grain price policy of the European Economic Community (EEC). During years of high world production, the inflexible target price system of the EEC tends to keep domestic demand lower than what it would otherwise have been. The excess supply in the EEC is released to world markets which, in turn, pushes world prices even lower than what they would otherwise have been. The opposite is true during years of low world production. This observation stresses the need for international cooperation in both the harmonization of pricing policies and the administration of adequate grain reserves.

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[4] The authors recognize that stabilizing feed grain prices also has an effect on wheat prices. This relationship would have to be worked out in detail before price stabilization policies are introduced.

[5] Johnson demonstrates this by a hypothetical example where only half of the world following stabilization policies doubles the price variability for the rest of the world unless there exist stocks to negate supply fluctuations.

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The Impact of Technical Change on Income Distribution: The Case of Rice in Colombia

Grant M. Scobie and Rafael Posada T.

A national rice research program adapted and developed modern rice varieties for irrigated culture. Their rapid and widespread adoption led to substantial increases in production, and a concomitant fall in the price of rice. This paper examines the incidence of both the gross benefits and the costs of the research program, by income level. As rice is a principal foodstuff, the net benefits, both absolute and relative, accrued disproportionately to the poorest households.

Key words: Colombia, income distribution, research, rice, technical change.

The contribution of technical change to agricultural productivity in developing countries has been widely recognized and increasingly documented (Arndt, Dalrymple, Ruttan). The generation of that technical change through agricultural research is now viewed as an economic activity to which scarce resources can be devoted and measurable output defined (Schultz).

In the appraisal of potential or past research strategies, two central economic issues arise: efficiency and equity. While earlier studies were concerned primarily with the efficiency goal, increasing attention has been given to the distribution of social benefits stemming from programs of agricultural research. Akino and Hayami, and Ramalho de Castro and Schuh examine the distribution of the gross social benefits between consumers and producers, while others have considered the impact on the functional distribution of income (e.g., Ayer and Schuh, Schmitz and Seckler, Wallace and Hoover).

In this paper we analyze the impact of technological change in the Colombian rice industry, giving particular attention to the consequences for the household income distribution. "It appears that relatively little theoretical and empirical work has been done on the welfare or income distributional effects of technical change. This is unfortunate, for a considerable amount of research funds is spent each year by both private and public institutions to develop new technologies for agriculture" (Bieri, de Janvry, Schmitz, p. 801). After sketching the background of the research program, we present some estimates of the social benefits: the rate of return (efficiency) and the impact on household income distribution (equity). Both costs and benefits of the research program are used in deriving the distributional consequences.

Background

In 1957 a national rice research program was formed within the Ministry of Agriculture with the cooperation of the Rockefeller Foundation (Rosero). At that time, the tall U.S. variety, Bluebonnet-50, was extensively grown; but in 1957 it was attacked by a virus disease, causing extensive losses. Imports of rice rose substantially, and the real domestic retail price was higher in 1957 than in any year since 1950 (and in fact, up to 1974). These events stimulated the formation and funding of a national rice research program whose primary objec-

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The research on which this article is based was conducted while the authors were economists in the Rice Program of the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia. The support and interest of John L. Nickel, director-general of CIAT and Peter R. Jennings, of the Rockefeller Foundation, are gratefully acknowledged. G. Edward Schuh, Paul R. Johnson, Alberto Valdés, Per Pinstrup-Andersen, Reed Hertford and two *Journal* reviewers all offered insightful comments.

tive was the selection of varieties resistant to the virus. By this mechanism it was hoped that domestic output could be increased, partly eliminating the need for rice imports and lowering domestic prices. This strongly consumer-oriented policy contrasts with the vacillation of public policy between a consumer and a producer focus which had been characteristic of Colombian rice policy since the thirties (Leurquin).

This research effort did produce new varieties, but their impact was limited (Hertford et al.). In 1967, the newly formed rice program of the Centro Internacional de Agricultura Tropical (CIAT) joined in a collaborative effort with the Colombian program, and dwarf lines from the International Rice Research Institute in the Philippines were introduced. This was followed by the local development and release of four disease-resistant dwarf rices. The rate of adoption of these modern varieties has been spectacular. In 1966, 90% of the irrigated sector was sown to the traditional variety (Bluebonnet-50); by 1974, virtually all the irrigated rice production came from dwarf varieties.

The research program, especially since 1967, has been oriented to the irrigated sector. The modern varieties have been best suited to areas with good water control and high levels of other inputs. Thus, while widely adopted throughout the irrigated sector, they had little impact in the upland or rainfed sector. Given the possibility of rapid increases in national output through the introduction of new varieties suited to irrigated culture, this was undoubtedly a rational choice. The rate of technological progress which could have been achieved with the same research resources surely would have been less had attention been directed to the upland sector. A further explanation of the particular ecological orientation adopted lay in the close collaboration between FEDEARROZ, the National Rice Growers' Federation (founded and supported principally by the large rice growers) and the research program.

As a consequence of the emphasis on the irrigated sector together with the rapid adoption of the modern varieties, yields and production in that sector rose dramatically. In contrast, the relatively disadvantaged upland sector which experienced little or no technical change declined in importance from 50% of the national output in 1966 to 10% in 1974.

The Model

The approach taken closely follows the formulation of Ayer and Schuh.[1] A formal statement of the supply and demand framework employed is given in the appendix. A more detailed statement of the model and the estimation of the parameters is given in Scobie and Posada. The model estimates the total gross social benefits and their division between Colombian rice producers and consumers, but extends existing formulations (following Bell) by distinguishing between upland and irrigated producers. This distinction was made as a consequence of the differential impact of the research program on the two sectors. It is suggested that the proposed formulation would have general applicability in analyzing the differential impact of a new technology whose relevance is restricted for whatever reason to a subset of the producing firms.

Results

Gross Benefits

The changes in consumer and producer surpluses resulting from the introduction of modern varieties were estimated for each year from 1964 to 1974 and are summarized in table 1. Consumer benefits are positive because, in the absence of modern varieties, the volume of rice entering the domestic market would have been much lower, with a concomitant higher internal price. However, for the same reason, both upland and irrigated producers have foregone rents to factors of production whose mobility is limited in the short run. Changes in producer surplus follow as a consequence of some inelasticity in the supply of rice, imparted by rising short-run marginal cost curves. Such changes would be transitory if, in the long run, the supply elasticities of all factors to rice production approached infinity. Despite the overall reduction in short-run producer surpluses, some gains undoubtedly accrued to "early adopters" in the irrigated sector.

[1] Hertford and Schmitz provide a review of the procedures involved in estimating changes in consumer and producer surplus. A valuable survey with discussion of some of the contentious issues is given by Currie, Murphy, and Schmitz, while some apparent inconsistencies between alternative formulations are noted by Scobie.

Table 1. Gross Benefits of New Rice Varieties in Colombia to Consumers and Producers

Gross Benefits Accruing to:	1964–69	1970–74
	------ $(Col.)m. ------	
Consumers	1,404	17,542
Producers		
Irrigated	−368	−6,468
Upland	−517	−3,878
Total	519	7,196

Note: Each entry is the sum of the annual deflated values (1964 = 100).

Had Colombia not mounted a successful research program, then upward pressure on domestic prices may well have been contained by allowing rice imports. Even in the absence of such approval, illegal imports from neighboring Venezuela and Ecuador may have had a price-depressing effect. Higher imports of rice would have reduced the amount of foreign exchange available for other imports and put upward pressure on the exchange rate. However, estimating the distributional consequences of this scenario would lead us far beyond the more modest scope of this investigation.

Net Benefits

The distribution of gross benefits between producer and consumer groups is a relatively blunt tool for analyzing the distributional impact of technological change. We attempt two extensions: first we will consider the incidence of the research costs, and so derive net benefits to producers and consumers; subsequently we examine the distribution of the gross benefits and research costs by income level within groups.

The costs of the research program were borne by three entities: (*a*) the national rice program of the Instituto Colombiano Agropecuario (ICA); (*b*) the contribution of the growers through FEDEARROZ under Law 101 of 1963, which created the *Cuota de Fomento Arrocera*. This law requires the collection of \$(Col.) 0.01/kg. from all growers, and authorizes FEDEARROZ to administer the funds for support of research, regional testing, publishing technical bulletins, presenting training courses to field agronomists, and financing the Technical Division of FEDEARROZ; and (*c*) international cooperation, originally through the Rockefeller Foundation and subsequently through the rice program of the Centro Internacional de Agricultura Tropical (CIAT).

No attempt is made to include any costs incurred by the International Rice Research Institute (IRRI) in the development of IR-8 and IR-22 which occupied up to almost 60% of the area sown in Colombia. Hence, for these varieties we will overstate the net global benefits by allowing their contribution to production without discounting their full costs. However, if the measurement of net benefits is viewed from Colombia's standpoint, then it is valid to include only those costs incurred by Colombia in testing, multiplying, and releasing the IRRI materials.

The distribution of gross social benefits, research costs, and net benefits for producers and consumers is shown in table 2. The gross social benefits were totalled for the period

Table 2. Size and Distribution of Benefits and Costs of Modern Rice Varieties in Colombia: 1957–1974

Item	Producers			Consumers	Total Colombia	International Cooperation[a]
	Upland	Irrigated	Total			
				$(Col.)m.		
Gross benefits	−3,542	−5,293	−8,835	14,939	6,104	—
Costs of research						
FEDEARROZ	8	30	38	—	38	—
ICA[b]	1	2	2	22	25	
Total	9	32	40	22	63	19
Net benefits	−3,551	−5,325	−8,875	14,917	6,042	—

Note: All data expressed in 1970 pesos; minor discrepancies are due to rounding.
[a] From Ardila (1973), and personal communication from the Centro Internacional de Agricultura Tropical (CIAT).
[b] From Ardila (1973), and personal communication from the Instituto Colombiano Agropecuario (ICA).

1964–74 and expressed in \$(Col.)m. 1970, compounding forward the years 1964–69 and discounting 1971–74, both using an estimate of 10% for the social opportunity cost of capital in Colombia (Harberger, p. 155).

In a similar manner the costs of the research from the three sources were summed and are shown in table 2. The costs of the ICA program were assumed to come from general tax revenue and were divided between consumers and producers on the basis of urban and rural proportions of total tax revenues in 1970 (Jallade). The producer contribution was further broken down between upland and irrigated producers on the basis of the production coming from each sector in 1970. The contributions from FEDEARROZ were distributed between the upland and irrigated sectors assuming a 45% collection rate (FEDEARROZ, 1975), except that no contributions were assumed for upland producers with less than 10 hectares. Expressed in 1970 pesos, \$(Col.) 82 m. were devoted to rice research between 1957 and 1974.

In order to assess the sensitivity of the net benefits to varying assumptions about the supply-demand elasticities, the results in table 3 were calculated. The demand elasticity was varied from −0.3 (a typical lower bound found in a review of numerous studies in developing countries) to −0.449 (based on Pinstrup-Andersen, de Londoño, Hoover, p. 137) to −0.754 (Cruz de Schlesinger and Ruiz). The supply elasticity of 0.235 is from Gutiérrez and Hertford, with an arbitrarily chosen upper value of 1.5.

The internal rate of return on the investment is consistently high and relatively insensitive to varying elasticities. These high returns are

Table 3. Net Benefits in 1974 and Internal Rates of Return for Differing Elasticities of Supply and Demand

Elasticity of Supply (ϵ)	Elasticity of Demand (η) −0.300	−0.449	−0.754
	--------	\$(Col.)m.	--------
0.235	9,052 89%	3,981 94%	2,174 89%
1.500	8,627 96%	3,556 87%	1,749 79%

Note: In each cell, the upper figure is the net benefits to Colombia of the rice research program in 1974, and the lower figure is the internal rate of return based on the period 1957–74, with the last year's costs and returns assumed to continue until 1986. The combination of $\eta = -0.449$ and $\epsilon = 0.235$ was used in calculating the results presented in tables 1 and 2.

not uncommon in agricultural research. Ayer and Schuh (p. 581) report an internal rate of return of 89% for cotton in São Paulo, Brazil; Akino and Hayami (p. 8) report values up to 75% for rice in Japan; Peterson (p. 669) reports 20% to 30% for poultry in the United States; Barletta reports 75% for wheat in Mexico; Griliches reports 35% for corn in the United States; Ardila reports 58% to 82% for rice in Colombia up until 1971; and Montes reports 76% to 96% for soybeans in Colombia. One should resist the conclusion that all agricultural research would show such payoffs—the literature is not replete with evaluations of failures.

While the net benefits in 1974 vary little with the supply elasticity they fall markedly with higher absolute demand elasticities (table 3). However, our concern here is more with the relative distribution of the net benefits within groups, rather than establishing their absolute magnitude.

Distribution of Net Benefits by Income Level

To evaluate the distributional impacts of the technological change, the gross benefits, the costs of the research program, and the consequent net benefits were distributed across income groups for consumers and upland and irrigated producers. In each case the annual average impact for 1970 was estimated by summing the gross benefits and costs (expressed in 1970 pesos), and dividing by the appropriate number of years.

Gross benefits to consumers were assumed to be directly proportional to the quantity of rice consumed, while their contributions to the research costs were distributed in proportion to tax receipts from each income stratum. The resulting net benefits to consumers by income level are shown in table 4.

Rice is now virtually the most important foodstuff in Colombia; between 1969 and 1974 total domestic consumption doubled (U.S. Department of Agriculture, p. 11), and rice is the major source of calories and the second major source of protein (after beef) in the Colombian diet (Departamento Nacional de Planeación). As rice is disproportionately consumed by the lower income groups who make limited tax contributions, the net benefits of the research program were strongly biased toward them in both absolute and relative terms. While the lower 50% of Colombian households received about 15% of household

Table 4. Distribution of Net Benefits, Households, and Household Income

1970 Income Level	Annual Average Net Benefits	Net Benefits as a Percentage of Income[a]	Cumulative Percentage of: Net Benefits	Households[b]	Household[b] Income
$(Col.)000	$(Col.)	(%)			
0–6	385	12.8	18	19	2
6–12	642	7.1	50	39	8
12–18	530	3.5	67	52	15
18–24	333	1.6	77	64	23
24–30	348	1.3	83	71	29
30–36	353	1.2	88	76	35
36–48	342	0.8	93	82	43
48–60	200	0.4	95	86	51
60–72	128	0.2	96	89	57
72+	138	0.2	100	100	100

[a] Relative to the midpoint of the interval.
[b] From Jallade, p. 22.

income, they captured nearly 70% of the net benefits of the research program.

In the case of producers, the annual average change in producer surplus was distributed across farm sizes in proportion to estimates of the production based on census data. The research costs were also distributed by farm size assuming that tax payments were proportional to production (in the case of the ICA costs), and by the method already discussed for the research levy. The sum of the foregone income and the research costs were then expressed as a percentage of the estimated 1970 average net income by farm size for the entire rural sector (table 5). This last step is clearly less than satisfactory.

Ideally, income distribution data are required for upland and irrigated rice producers by size of farm. As no such data are known to exist, resort was made to a distribution of rural income by farm size for 1960 (Berry, p. 610), inflated to 1970 values. We have no basis for knowing whether rice producers would have higher or lower incomes than the rural average for each farm size group. However, again, our principal interest is in the relative rather than absolute distribution of benefits by income level.

The group most severely affected was the small (i.e., low-income) upland producers. For these producers, the annual average income foregone through lower rice prices (and no compensating technological change), represented a high proportion of their assumed 1970 income. To the extent that their incomes were below the rural sector average, this impact would have been even more pronounced. On the other hand, the foregone income to the irrigated producers varied more erratically depending on the size group, with the heaviest relative burden falling on the 200–500 and 500–1,000 hectare groups. However, the absolute impact may well be overstated if irrigated producers had incomes above the national average for rural income earners.

In summary, the net benefits of the techno-

Table 5. Annual Average Distributional Impact of Rice Research Program on Upland and Irrigated Producers

Farm Size	Average Income[a]	Change in Producer Surplus Plus Research Costs as a Percentage of 1970 Income: Upland Sector	Irrigated Sector
(hectares)	$(Col.)	(%)	
0–1	1,500[b]	−58	−56
1–2	3,647	−53	−39
2–3	5,330	−60	−25
3–4	6,508	−71	−38
4–5	7,406	−75	−53
5–6	10,295	−60	−43
10–20	15,652	−48	−47
20–30	18,934	−41	−48
30–40	23,394	−35	−47
40–50	28,620	−30	−45
50–100	35,904	−29	−48
100–200	66,759	−26	−53
200–500	155,398	−18	−79
500–1,000	287,513	−21	−69
1,000–2,000	532,389	−19	−49
2,000–+	1,480,199	−11	−36

[a] From Berry (1974, p. 610), adjusted to 1970.
[b] Assumed value.

logical change accrued to consumers, with the lowest income households capturing a disproportionate share. As Hayami and Herdt note, "The decline in the price of a food staple due to technical progress in its production has the effect of equalizing income among urban consumers" (p. 249). The foregone income to producers appeared to fall most heavily on the small upland producers. Even if the average annual consumer benefits are included as benefits to upland producers, the small upland producers still appear as the most severely affected, a not surprising result, given the orientation of the research program toward the irrigated sector. However, some notion of the relative magnitudes of the different groups should be borne in mind. In 1970 (prior to the major impact of the modern varieties) there were only an estimated 12,000 upland producers with less than 5 hectares. Hence, under any plausible set of welfare weights, their losses would be more than offset by the gain to more than 1 million low-income consuming households, implying an overall gain (albeit uncompensated) in some measure of social welfare.

Caution should be exercised in generalizing from this conclusion. The urban and nonlandowning rural poor of Colombia are very much more numerous than the small farmer. In less urbanized countries with a large semisubsistence rural population, the lowest income households may benefit from technological advances specifically designed for the small farm sector (Valdés, Scobie, Dillon).

Concluding Comments

Concern is periodically voiced for the distributional implications of technological change in developing agriculture. One is often led to feel that the introduction of new technology has been only a qualified success because of its apparent failure to solve a broad spectrum of social ills. But frequently it is the well-being of only the rural poor (both the small farmer and the landless worker) that is the focus of attention. The presence of large concentrations of urban poor who are potential beneficiaries of expanded production of basic foodstuffs is sometimes neglected when castigating the "green revolution."

Throughout much of Latin America, the rural poor tend to be concentrated (for historical reasons) in the less favored ecological zones. The development of technology suited to such areas is presumably a more difficult process, which *ceteris paribus*, would divert research resources from the discovery of technologies which can result in rapid increases in total output from the more favored commercial agricultural sector.

The results presented for the case of Colombian rice exemplify this tradeoff. By focussing on the distribution between consumers and producers, and, more important, by isolating both the costs and benefits by income strata, we have endeavored to quantify some of the dimensions of this tradeoff. Concentrating the research on the upland producers would presumably have entailed foregone benefits to the numerous urban poor (without guaranteeing that small upland producers would have benefitted in the long run).

This paper has attempted some preliminary extensions of the commonly used approaches to analyzing the distributional impact of technological change: (*a*) a model which allows for differential impact of technological change on two classes of producers is introduced; (*b*) the incidence of research costs is considered in the distribution of the social benefits to different groups; and (*c*) the distributional impact (at the national level) on consumer and producer households by income strata is analyzed. These extensions have come only at a price. We have ignored the consequences for the employment of resources released from the rice sector due to the differential impact of the new technology; and the lack of data to analyze the distributional consequences for household income led us to a formidable number of assumptions, we hope not excessively cavalier.

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Appendix

Supply and Demand Relationships

The supply and demand relationships used to estimate the gross social benefits, together with the changes in consumer and producer surpluses (irrigated and upland) were:

$$\text{Demand:} \quad P_t = \alpha_t Q_{T,t} \cdot \exp(1/\eta);$$

Supply

$$\text{Irrigated: } Q_{I,t} = \beta_t P_{t-1} \cdot \exp(\epsilon_I),$$
$$\text{Upland: } Q_{U,t} = \gamma_t P_{t-1} \cdot \exp(\epsilon_U),$$

and

$$\text{Total: } Q_{T,t} = \delta_t P_{t-1} \cdot \exp(\epsilon);$$

Identities

$$\text{Production: } Q_{T,t} \equiv Q_{U,t} + Q_{I,t},$$

and

$$\text{Supply Elasticities: } \epsilon \equiv \rho\epsilon_I + (1 - \rho)\epsilon_U,$$

where P_t is the deflated farm price; Q is output from the irrigated (I), upland (U) and total (T) rice sectors; η is the demand elasticity; ϵ_I, ϵ_U and ϵ the supply elasticities of irrigated, upland, and total rice respectively; and ρ is the fraction of output from the irrigated sector. In the absence of technical change, the supply curves for the irrigated and total sectors would be displaced by k percent, k reflecting the yield superiority of the modern varieties and the proportion of the area on which they were sown.

Alternative Estimates of Static and Dynamic Demand Systems for Canada

Richard Green, Zuhair A. Hassan, and S. R. Johnson

Selected static and dynamic demand systems are applied to Canadian data for the period 1947–1972. Four commodity groups—durables, semi-durables, services and nondurables—are used for the major portion of the analysis. For the static systems, results for nine commodity groups are provided as a comparison. Income and price elasticity estimates, following from the static systems are, with the exception of the double log, proved reasonably similar. The estimates from the two dynamic systems, the dynamic linear expenditure and state adjustment models, appeared more plausible particularly for services and durable goods, where persistence in consumption patterns is generally observed. As related to other estimates from United States and Canadian data, these results seem to be more stable and more in agreement with a priori reasoning.

Key words: consumer demand, price and income elasticities, systems estimation.

While a substantial literature has developed on demand systems applications, few studies permit comparisons of results for the alternative specifications obtained from the same data base. Such comparisons are useful for a more complete understanding of consumer behavior as well as for evaluating the various demand systems models in an applied context. Static and dynamic forms of similar systems, results at different aggregation levels, and more complete comparisons with estimates from other studies afford a rich basis for evaluating the demand systems approaches.

This paper contains results of a comprehensive application of the major demand systems models to data on the Canadian economy. Annual observations for 1947–1972 are used as the data base. Estimates for three static and two dynamic systems are obtained using the data aggregated to four commodity groups. Two static and a double log system are also estimated for nine commodity groups. Results for the estimated models are then compared among themselves and to similar studies for Canada and the United States.

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The plan of the paper is as follows. First, a brief review of the static and dynamic demand systems is presented and the statistical assumptions on which the estimation methods are based are summarized. Then, the sample data and commodity groups are described. Next the results are discussed, and the performance of the models is evaluated. Finally, some concluding remarks based on the empirical results are offered.

Demand Systems

The purpose of this section is to set out the notation and examine the theoretical and behavioral implications of three static demand systems. As each of the systems is fully developed elsewhere, the derivations are omitted.

Static Demand Systems

Demand Functions Derived from Utility Maximization. Two widely used utility function-based approaches to demand systems estimation are the linear expenditure and the indirect addilog models.[1] The linear expenditure system is derived from the utility function suggested by Klein and Rubin:

$$u = \mu' \log(q - \gamma), \tag{1}$$

[1] The extended linear expenditure system (Lluch, 1973) and flexible systems are other utility-function based approaches.

where $q = [q_i]$ denotes an n-element column vector of quantities for the commodities, $\mu = [\mu_i]'$ is the n-component vector of marginal budget shares, and $\gamma = [\gamma_i]'$ is a vector of elements to be interpreted as minimum required quantities. The parameters μ_i and γ_i are estimated with the restrictions $0 < \mu_i, < 1, \Sigma\mu_i = 1$, and $(q - \gamma) > 0$. Maximizing this utility function subject to the budget constraint yields a system of demand functions

$$(2) \qquad q = \gamma + (m - p'\gamma)\bar{p}^{-1}\mu,$$

where $p = [p_i]$ is an n-element vector of commodity prices, m is money income, and $\bar{p}$ denotes an $n \times n$ diagonal matrix, with nonzero elements given by the vector p (Stone). These demand functions are homogeneous of degree zero in prices and income, satisfy the adding-up criterion, and have a matrix of substitution terms that is symmetric and negative semidefinite (Yoshihara, p. 263).

Expenditure equations corresponding to the demand system (2) take the form

$$(3) \qquad p_i q_i = p_i\gamma_i + \mu_i(m - \sum_j p_j\gamma_j).$$

According to equation (3), the consumer may be viewed as purchasing minimum required quantities of each commodity, γ_i. At current market prices these quantities cost $\sum_j p_j\gamma_j$. The remainder of the available income $(m - \sum_j p_j\gamma_j)$ is then distributed over the commodities in fixed proportions, μ_i. Hence, $\sum_j p_j\gamma_j$ and $(m - \sum_j p_j\gamma_j)$ can be considered as "subsistence" and "supernumerary" incomes, respectively.[2]

The income (η_i), own price (e_{ii}), and cross price elasticities (e_{ij}) can be calculated directly from equation (3). Expressions for the income and price elasticities, along with other information for comparing this and the demand systems to follow, are contained in table 1. With $w_i = p_iq_i/m$ and $\mu_i > 0$, all income elasticities are positive. For the own price elasticities, the conditions $0 < \mu_i < 1$ and $q_i - \gamma_i > 0$ insure that the calculated values will be negative. Cross price elasticities are given by the expression $e_{ij} = -\mu_i/(p_j\gamma_j/p_iq_i)$. Clearly all are negative, unless some of the γ_i's are negative. Thus, both inferiority and complementarity are excluded, a consequence of the directly additive utility function.

Houthakker has derived a related demand system using the indirect utility function. The indirect utility function specifies the maximum utility level for a given set of prices and a particular income

$$(4) \qquad u^*(p,m) = \sum_i a_i(m/p_i)^{b_i},$$

where a_i and b_i are parameters with $a_i < 0, \Sigma a_i = -1$, and $-1 < b_i < 0$. Explicit solutions for the demand functions can be obtained by differentiating equation (4) with respect to prices and income and applying Roy's identity. Equations in the resultant demand system are of the form

$$(5) \quad q_i = \frac{a_ib_im^{b_i}p_i^{-b_i-1}}{\sum_j a_jb_jm^{b_j-1}p_j^{-b_j}} = \frac{a_ib_i\left(\frac{m}{p_i}\right)^{1+b_i}}{\sum_j a_jb_j\left(\frac{m}{p_j}\right)^{b_j}}.$$

These demand functions are also homogeneous of degree zero in income and all prices, and satisfy the Engel aggregation and Slutsky symmetry conditions (Yoshihara, p. 264). Own price, cross price and income elasticities are easily obtained from equation (5) and shown in table 1. Since $-1 < b_i < 0$, $\eta_i \gtreqless 1$ according to whether $b_i \gtreqless \sum_j b_jw_j$. From the related expression for the own price elasticities observe that with $-1 < b_i < 0$ and $w_i > 0$ they are bounded by minus one and zero. The cross price elasticities are obtained as $e_{ij} = b_jw_j$ and negative for admissable values of b_j. The cross price elasticities depend only on the commodity for which the price is changing.

A Demand System Specified Directly. The relative price version of the Rotterdam model Theil and Barten proposed is as follows (Barten 1964, 1968, 1969, 1977; and Theil 1967, 1971):[3]

$$(6) \quad w^*_{it}\Delta(ln q_{it}) = \sum_j b_{ij}[\Delta(ln p_{jt}) - \sum_k \mu_k \Delta(ln p_{kt})] + \mu_i\Delta(ln q_t),$$

where $w^*_{it} = 1/2(w_{it} + w_{it-1})$, $b_{ij} = \lambda p_ip_j\mu^{ij}/m$, $\mu_i = p_i(\partial q_i/\partial m)$, the Δ's denote changes between years and finally, λ is the marginal utility of income, and μ^{ij} is the ij^{th} element of the inverse of the Hessian matrix identified with

[2] This interpretation holds when γ_i is positive, a restriction not implicit in the specification of the system.

[3] Powell's (1966) system of additive preferences is also a demand system specified directly. Of the other static demand systems some, e.g., the double *log*, are inconsistent with restrictions imposed by the standard theory.

Table 1. A Summary of Demand Systems Characteristics

Demand System	Utility Function	Functional Form	Constraints: Engel	Constraints: Symmetry	Constraints: Homogeneity	Elasticities: Income (η_i)	Elasticities: Price (e_{ii})	Number of Parameters Estimated
Linear Expenditure	$u = \mu' \log(q - \gamma)$	$\bar{p}q = \bar{p}\gamma + (m - p\gamma)\mu$	Holds	Holds	Holds	μ_i / w_i	$-1 + (1 - \mu_i)\frac{\gamma_i}{q_i}$	$2n$
Indirect Addilog	$u^* = \Sigma_i a_i (m/p_i)^{b_i}$	$q_i = \frac{a_i b_i (m/p_i)^{1+b_i}}{\Sigma_j a_j b_j (m/p_j)^{b_j}}$	Holds	Holds	Holds	$(1 + b_i) - \Sigma_j b_j w_j$	$-(1 + b_i) + b_i w_i$	$2n$
Rotterdam	—	$w^*_{it}\Delta(\ln q_{it}) = \phi\mu_i[\Delta(\ln p_{it})$ $- \Sigma_k \mu_k \Delta(\ln p_{kt})] + \mu_i \Delta(\ln q_t)$	Holds	Holds	Holds	μ_i / w_i	$\phi\eta_i - \eta_i w_i(1 + \phi\eta_i)$	$n + 1$
Double-Logarithmic	—	$q_i = A_i m^{\eta_i} \Pi_j p_j^{e_{ij}}$	—	—	—	η_i	e_{ii}	$n^2 + n$
State Adjustment	—	$q_i = \theta_i + \alpha_i s + \kappa_i m + \nu_i p$	—	—	—	(SR) $\kappa_i \frac{m}{q_i}$	(SR) $\nu_i \frac{p_i}{q_i}$	$5n$
						(LR) $\frac{\kappa_i \delta_i}{\delta_i - \alpha_i} \frac{m}{q_i}$	(LR) $\frac{\nu_i \delta_i}{\delta_i - \alpha_i} \cdot \frac{p_i}{q_i}$	
Linear Expenditure (Dynamic)	$u = \mu' \log(q - \theta - \bar{\alpha}s)$	$q = (\theta + \bar{\alpha}s) + (\iota'\mu)^{-1}\bar{p}^{-1}$ $\mu(m - p'(\theta + \bar{\alpha}s))$	Holds	Holds	Holds	(SR) $\mu_i / (\Sigma \mu_i) w_i$	(SR) $\phi\eta_i - \eta_i w_i (1 + \phi\eta_i)$	$4n$
						(LR) μ^*_i / w_i	(LR) $-1 + (1 - \mu^*_i)\frac{\gamma^*_i}{q_i}$	

the second-order conditions of the consumer maximization problem. When the additivity condition is imposed, the demand equation (6) can be simplified to

$$(7)\quad w^*_{it}\Delta(lnq_{it}) = \phi\mu_i[\Delta(lnp_{it}) - \sum_k \mu_k \Delta(l\,np_{kt})] + \mu_i \Delta(l\,nq_t),$$

where ϕ is the reciprocal of Frisch's money flexibility $(\omega = \frac{\partial\lambda}{\partial m}\frac{m}{\lambda})$. In this form the demand functions contain only $n + 1$ parameters, the μ_i and ϕ.

As shown in table 1, the income elasticities are given by ratios μ_i/w_i and thus restricted to be positive. Also, the commodity group is income elastic or inelastic, depending upon the inequality, $\mu_i \gtreqless w_i$. The own price elasticity expression can take both positive and negative values. The cross price elasticity is $e_{ij} = (b_{ij}\mu_j - w_j\mu_i)w_i$. These expressions for the price elasticities can be simplified; that is, $e_{ii} = \phi\eta_i - \eta_i w_i(1 + \phi\eta_i)$ and $e_{ij} = -\eta_i w_j(1 + \phi\eta_j)$, in the case of additive preferences (i.e., for $b_{ii} = \phi\eta_i$). From the simplified expressions it follows that $e_{ij} \gtreqless 0$, according to $|\eta_i w_j \phi\eta| \gtreqless |\eta_i w_j|$. For example, if $|\eta_i w_j| > |\eta_j w_j \phi\eta_i|$, then $e_{ij} < 0$ and the cross price elasticity reflects the income effect rather than the substitution effect of the price change.

Dynamic Demand Systems

The first of the two "dynamic" systems reviewed is the state adjustment model of Houthakker and Taylor.[4] The state adjustment model at time t can be expressed as

$$(8)\qquad q_{it} = \theta_i + \alpha_i s_{it} + \kappa_i m_t + \nu_i p_{it},$$

where q_{it} is the (rate of) demand, m is the rate of income, p_{it} is the relative price, s_{it} is the stock of the commodity and may be viewed either as a physical stock (in case of durable goods) or psychological stock of habits (in case of habit-forming goods), and θ_i, α_i, κ_i, and ν_i are the underlying structural parameters. According to the interpretation of the model, $\alpha_i > 0$ for habit-forming goods and $\alpha_i < 0$ for durable goods. It is further assumed that

$$(9)\qquad \dot{s}_i = q_{it} - \delta_i s_{it},$$

where $\dot{s}_i$ denotes the rate of change in stock, ds_{it}/dt, and δ_i is a constant depreciation rate, normally taken to be positive.

For empirical implementation, the unobservable variable s_{it} is eliminated by combining equations (8) and (9). After differentiation of the resulting expression with respect to time and using the discrete approximation $\dot{s}_i = s_{it} - s_{it-1}$ and $s_{it} = ½(s_{it} + s_{it-1})$ and suppressing the commodity subscripts (i) for the parameters, the model is

$$(10)\quad q_{it} = \frac{\theta\delta}{1 - ½(\alpha - \delta)} + \frac{1 + ½(\alpha - \delta)}{1 - ½(\alpha - \delta)} q_{it-1} + \frac{\kappa(1 + ½\delta)}{1 - ½(\alpha - \delta)} \Delta m_t + \frac{\kappa - \delta}{1 - ½(\alpha - \delta)} m_{t-1} + \frac{\nu(1 + ½\delta)}{1 - ½(\alpha - \delta)} \Delta p_{it} + \frac{\nu\delta}{1 - ½(\alpha - \delta)} p_{it-1},$$

or in more convenient form,

$$(11)\quad q_{it} = A_{i0} + A_{i1}q_{it-1} + A_{i2}\Delta m_t + A_{i3}m_{t-1} + A_{i4}\Delta p_{it} + A_{i5}p_{it-1}.$$

The A's along with the condition $A_{i2}A_{i5} = A_{i3}A_{i4}$ can be solved for unique values of the underlying structural parameters.

The short-run derivatives of consumption with respect to income and price are given by κ_i and ν_i, respectively. Long-run derivatives are obtained by assuming $\dot{s}_i$ as shown in equation (9) equal to zero, implying that the stock adjustment has reached an equilibrium state. Substitution of the resulting expression into equation (8) gives

$$(12)\ q_{it} = \frac{\theta_i\delta_i}{\delta_i - \alpha_i} + \frac{\kappa_i\delta_i}{\delta_i - \alpha_i} m_t + \frac{\nu_i\delta_i}{\delta_i - \alpha_i} p_{it}.$$

For $\delta_i \neq \alpha_i$, the long-run derivatives of consumption with respect to income and price are given by coefficients of m_t and p_{it}, respectively. Expressions for elasticities based on these coefficients of the long- and short-run forms of the demand functions are shown in table 1.

The second dynamic model to be applied is due Phlips (1972). It is a dynamic version of the linear expenditure system and can be developed by assuming that the elements of the parameter vector γ are linear functions of state variables

$$(13)\qquad \gamma = \theta + \hat{\alpha}s_t,$$

where $s_t = [s_{it}]'$, $\theta = [\theta_i]'$ and $\alpha = [\alpha_i]'$ are vectors of constants which may take positive

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[4] Intertemporal demand systems developed by Phlips (1974) and Lluch (1974) are recent attempts at specifying more completely dynamic demand models.

or negative values. An adjustment equation identical to (9) but in vector notation is used, i.e., $\dot{s} = q_t - \hat{\delta} s_t$ with $\dot{s} = [\dot{s}_i]'$, $\delta = [\delta_i]'$, and $\hat{\delta}$ is a diagonal matrix with nonzero elements δ_i.

Substitution of equation (13) for γ in equation (1) and maximization of the utility function subject to the budget constraint yields short-run demand functions of the form

$$(14)\quad q_{it} = (\theta_i + \alpha_i s_{it}) + \frac{\mu_i}{p_{it}(\Sigma \mu_i)} [m_t - \Sigma_j p_{jt}(\theta_j + \alpha_j s_{jt})].$$

Again, the corresponding long-run demand equations are derived on the assumption $\dot{s} = 0$. Using this result equation (14) becomes

$$(15)\quad q^*_{it} = \gamma^*_{it} + \frac{\mu^*_i}{p_{it}} (m_t - \Sigma_j p_{jt} \gamma^*_j),$$

where

$$\gamma^*_i = \frac{\gamma_i \theta_i}{\delta_i - \alpha_i}$$

and

$$\mu^*_i = \frac{\delta_i \mu_i/(\gamma_i - \alpha_i)}{\Sigma_j \delta_j \mu_j/(\delta_j - \alpha_j)}.$$

Here, γ^*_i is the long-run counterpart of the short-run parameter, θ_i, $\gamma^*_i > \theta_i$ when $\alpha_i > 0$, i.e., commodity i is habit forming, and $\gamma^*_i < \theta_i$ when $\alpha_i < 0$, i.e., commodity i is durable; and finally, μ^*_i is the long-run marginal budget share satisfying the condition $\Sigma_i \mu^*_i = 1$.

From equations (14) and (15) the short-run and long-run demand elasticities can be derived (table 1). For this purpose, in the short-run it is assumed $\partial s_{it}/\partial m_t = 0$. The expressions are of the same form as those obtained for the static linear expenditure system. However, the estimated values for the parameters are different, owing to the added structure provided by the dynamic adjustment mechanism. Finally, for empirical work, the unobservable state variables s_{it} are eliminated and the data are differenced to approximate instantaneous time rates of change. Making these adjustments in equation (14), the demand system becomes

$$(16)\quad q_{it} = \frac{2\delta_i \theta_i}{2 - \alpha_i + \delta_i} + \frac{2 + \alpha_i - \delta_i}{2 - \alpha_i + \delta_i} q_{it-1} + \frac{\mu_i(\delta_i + 2)}{2 - \alpha_i + \delta_i} \frac{1}{\lambda_t p_{it}} + \frac{\mu_i(\delta_i - 2)}{2 - \alpha_i + \delta_i} \frac{1}{\lambda_{t-1} p_{it-1}},$$

or

$$(17)\quad q_{it} = k_{i0} + k_{i1} q_{it-1} + k_{i2} \frac{1}{\lambda_t p_{it}} + k_{i3} \frac{1}{\lambda_{t-1} p_{it-1}}.$$

Structural coefficients for the dynamic linear expenditure system can be unambiguously calculated from the estimated regression coefficients for equation (17).

A Synthesis

Table 1 includes information on the utility function assumed (where appropriate), the functional form of the demand equation, an indication of whether or not the constraints imposed by the classical theory are satisfied, and the number of parameters to be estimated. Thus, it is a reference for evaluating alternative empirical demand systems. Of course, there are advantages and disadvantages to each approach. The important point is that each has certain theoretical and empirical implications which should be reflected in interpreting the applied results.

Estimation Methods

For empirical implementation, normal, additive error terms were included in the specifications for the linear expenditure and indirect addilog demand systems. These error terms were assumed to have zero means, contemporaneous variance-covariance matrix Ω, and to be intertemporally uncorrelated. Due to the adding-up criterion, the variance-covariance matrix is singular. When no autocorrelation exists, this singularity problem can be handled by arbitrarily deleting an equation from the system (Berndt and Savin). The resulting system has a positive definite contemporaneous variance-covariance matrix of full rank (Parks, Carlevaro and Sadoulet). The omitted equation as well as the full covariance estimator Ω, are then obtained by applying the Engel aggregation condition.[5]

For the Rotterdam model the estimation procedure of Barten and Theil is utilized. The stochastic nature of the demand equations is rationalized on the basis of a randomness associated with changes in the underlying utility

[5] The choice of this method was based largely on the availability of a specialized program for obtaining maximum likelihood estimates of the parameters for the linear expenditure and the indirect addilog systems (Carlevaro and Sadoulet).

function. These changes are assumed to be independent of income and prices. If it is assumed that this source of randomness is confined to the linear term in a quadratic approximation of the underlying utility function, then the stochastic component of consumption can be taken as an additive term in the demand functions. When this term is added along with the properties which derived from the assumptions implied by the model, an iterative least-squares procedure can be employed to approximate the optimal estimators.

The dynamic linear expenditure system and state adjustment model are modified to include additive error terms with the usual properties required for application of ordinary least squares. For the dynamic linear expenditure system, an iterative procedure (method D) suggested by Houthakker and Taylor (p. 202) is used. Initial values for λ_t are selected and ordinary least squares is applied to estimate the remaining parameters. Then, from the estimates of the coefficients obtained in step one, a new set of values for λ_t is obtained by making the calculation shown in Phlips (1974, p. 192). The process continues until the budget constraint is approximately satisfied for each time period. The state adjustment model was estimated using a non-linear least squares procedure under the aforementioned restrictions, $A_{i2}A_{i5} = A_{i3}A_{i4}$.

Data Sources and Commodity Groupings

Time-series (1947–1972) data on annual personal consumption expenditures and prices are used in estimating the parameters required for the demand systems to be studied. Personal consumption expenditure data for major commodity groups and services are based on official estimates of Statistics Canada. The other data required, implicit price indexes (1971 = 100) for the commodity groups, are also available from the same source. The price indexes are derived by dividing expenditure in current dollars by expenditure in constant dollars and are called implicit deflators. That is, the weights of the various components in the commodity groups shift with the changing composition of commodities or services over time. Finally, the population data used to obtain the per capita variables required for the analysis are for the mid-year (June 1) and available from Statistics Canada.

For the linear expenditure and the indirect addilog systems, the expenditure data ($p_{it}q_{it}$) is per capita current dollar personal expenditure on the i^{th} commodity. The price series (p_{it}) are implicit and indexed (1971 = 100). Income (m) is measured, using the per capita total personal expenditure in current dollars.

In the Rotterdam model a simple procedure was used to obtain the observations on the dependent variables. First, logarithms of the total quantities demanded were calculated, using $lnq_{it} = ln(p_{it}q_{it}) - lnp_{it}$. Next, the logarithm in midyear population was subtracted from the logarithm of quantity for each year, to obtain per capita quantity demanded. Finally, first differences were calculated and then multiplied by the average expenditure proportions. The income (total expenditure) variable in the Rotterdam model is derived as a sum of the values for the dependent variables.

In the state adjustment model, the quantity data (q_{it}) are per capita constant (1971) dollar expenditures on the i^{th} commodity. The price series are relative and obtained by dividing expenditure in current dollars by expenditure in constant dollars for each commodity group, and by deflating the results by the implicit price index for total personal expenditure on consumer goods and services. The income variable (m_t) is the total personal expenditure in constant dollars per capita. Finally, in the case of the dynamic linear expenditure system, the quantity data are in constant dollars. The price series (p_{it}) are implicit, and income (m_t) is total expenditure in current dollars per capita.

The major application of the demand systems models is to consumer expenditures aggregated into four groups: durable goods, semi-durable goods, nondurable goods, and services. These groups are mutually exclusive, account for the total expenditures of consumers, and follow principles of classification used by Statistics Canada. For comparison, two static systems and the double log model are applied for nine commodity groups. The classification in this case is by function and not type of good and again follows the classification system used by Statistics Canada.

Results

The major results for the models estimated using four commodity groups are reported first

Table 2. Basic Parameter Estimates for the Static Demand Systems

	Rotterdam Model		Linear Expenditure System		Indirect Addilog System		
Commodity Group	Price Coefficient b_{ii}	Marginal Budget Share μ_i	Minimum Required Quantity γ	Marginal Budget Share μ_i	c_i	b_i	Marginal Budget Share[b]
Durable Goods	−.1799	.2331	10.32	.1844	.0999	−.1539	.1934
	(.0571)[a]	(.0323)	(4.21)	(.0151)	(.0073)	(.1334)	
Semidurable Goods	−.0931	.1207	167.12	.0836	.1878	−.9665	.0853
	(.0370)	(.0226)	(2.70)	(.0052)	(.0065)	(.1793)	
Nondurable Goods	−.1764	.2287	333.60	.2373	.3956	−.8280	.2524
	(.0448)	(.0306)	(6.59)	(.0122)	(.0166)	(.1572)	
Services	−.3221	.4175	46.88	.4947	.3167	−.3083	.4689
	(.0993)	(.0486)	(24.23)	(.0293)	(.0279)	(.2870)	
Income Flexibility ϕ	−.7715						
	(.2162)						

[a] Standard errors are in parentheses.
[b] Calculated as the income elasticity multiplied by the expenditure share.

for the static systems and then for the dynamic systems.

Static Systems: Basic Parameter Estimates

Estimates of the parameters for the three static systems are presented in table 2. Referring first to those for the Rotterdam model, all the values for the coefficients are more than twice their estimated standard errors. The parameter estimates are also consistent with the qualitative restrictions implied by the behavioral assumptions and model structure. The estimated income flexibility coefficient (ϕ) is equal to -0.77. This implies that the marginal utility of income decreases by 1.30% in response to a 1% increase in income. The value is similar to the one (-1.55) reported by Powell (1965). Furthermore, this value (-1.30) lies between Frisch's (p. 189) money flexibility of -2 for the median part of the population and -0.7 for the better-off part of the population.

For the linear expenditure system, the estimated marginal budget shares are all positive, significantly different from zero on a statistical basis, and sum to 1. The estimated γ_i's represent minimal consumption levels for the various commodities and, as expected, are positive and range from 333.60 for nondurable goods to 10.32 for durable goods. Finally, the basic parameter estimates for the indirect addilog system appear to be as reliably estimated as those for the other systems shown in table 2. Additionally, the results are consistent with a priori reasoning. That is, all the estimates of the b_i's are negative and lie within the interval $(-1, 0)$. Likewise, all of the estimates of $c_i = a_i b_i$ are positive, as expected, and sum to 1.

For the three systems, variations in the estimated marginal budget shares are not substantial. Specifically, the results suggest that the budget shares for durables, semidurables, nondurables, and services are near .20, .10, .25, and .45, respectively. The stability of these parameters across systems specifications and estimation methods is encouraging for the appropriateness of commodity groupings, the separability assumptions, and more generally, the robustness of the results.

Static Systems: Elasticities

Income elasticities, direct price elasticities (compensated and uncompensated), and expenditure shares for the Rotterdam, linear expenditure, and indirect addilog systems are presented in table 3. All the income elasticities are positive, ranging from 1.69 for durables estimated from the Rotterdam model to .58 for semidurables for the linear expenditure model, indicating that the commodity groups are not inferior. This result is not surprising given the level of aggregation in the commodity groupings. The durable goods and services groups have estimated income elasticities which are greater than one. This implies that the commodities they contain include lux-

Table 3. Comparison of Elasticities Estimated from the Parameters for the Static Demand Systems

		Income Elasticity			Direct Price Elasticity					
					Uncompensated			Compensated		
Commodity Group	Expenditure Share	Rotterdam	Linear Expenditure	Indirect Addilog	Rotterdam	Linear Expenditure	Indirect Addilog	Rotterdam	Linear Expenditure	Indirect Addilog
Durable Goods	0.1375	1.69	1.34	1.40	−1.23	−0.96	−0.86	−1.00	−0.77	−0.67
Semidurable Goods	0.1435	0.84	0.58	0.59	−0.69	−0.44	−0.17	−0.57	−0.36	−0.08
Nondurable Goods	0.3446	0.66	0.68	0.73	−0.62	−0.59	−0.45	−0.39	−0.35	−0.20
Services	0.3744	1.11	1.32	1.25	−0.91	−0.96	−0.80	−0.50	−0.47	−0.33

uries; that is, goods for which expenditures increase more than proportionately with income. Alternatively, the semidurable and nondurable commodity groups have estimated elasticities which are less than one. This implies that the commodities of which they are composed are largely necessities. Consumption of such items tends to remain relatively stable irrespective of income levels.

Differences among the estimates obtained using the three systems are in some cases sizable. Generally, the estimates from the linear expenditure and indirect addilog systems compare more closely. The Rotterdam model produces notably higher income elasticity estimates for the durable goods and semidurable goods groups and a lower estimate for the services group. For example, in the case of durable goods, the income elasticity estimate for the Rotterdam model is 1.69, as contrasted with values of 1.34 and 1.40 for the linear expenditure and indirect addilog models, respectively.

The compensated price elasticity estimates are substantially lower than the uncompensated estimates. Generally, durable goods and services groups have price elasticities closer to −1. For durable goods, the range in uncompensated price elasticity estimates is from −1.23 for the Rotterdam model to −.86 for the indirect addilog model. In the case of services, a similar comparison shows a high value of −.96 for the linear expenditure system and a low value of −.80 for the indirect addilog model. The durables and services groups are composed of commodities that tend to be more price elastic. For the semidurable goods, the results are more variable, ranging from −.17 for the indirect addilog system to −.69 for the Rotterdam system. Aside from this result, the estimates from the three systems are rather similar. Price elasticities from the Rotterdam model are, in general, the highest. In fact, the one exception is for services in the linear expenditure system. The lowest price elasticity estimates are for the indirect addilog system.

Dynamic Systems: Basic Parameter Estimates

Estimates of the basic parameters for the state adjustment model are reported in table 4. Most of the parameter estimates are statistically significant at the 5% level. A priori restrictions on these basic parameter estimates, following from the structural model, are minimal. However, all of the A_1 estimates, the parameter on q_{t-1}, are positive and in the unit interval. The parameter estimates on Δp_t, (A_4), are negative, as expected, with the sign determined by the price coefficient ν in the structural model equation (8). Finally, the parameter estimates on the income terms A_2 and A_3 are positive. Thus income levels and increments to income are positively related to consumption levels for the four aggregated commodity groups.

Results for the basic parameters of the dynamic linear expenditure system are shown in table 5. All regression coefficients are significantly different from zero at the 5% level, and all of the estimated coefficients have correct signs according to a priori reasoning. In general, the results for the basic parameters are quite favorable when compared with the theory and previous results for the United States (Phlips, 1974).

Table 4. Estimates of Basic Parameters for the State Adjustment Model

Commodity Group	A_0	A_1	A_2	A_3	A_4	A_5
Durable Goods	10.58	.4843	.3355	.0879	−223.63	−58.59
		(.1286)[a]	(.0401)	(.0268)	(93.75)	
Semidurable Goods	16.46	.8448	.1676	.0164	−93.65	−9.16
		(.0729)	(.0169)	(.0062)	(52.29)	
Nondurable Goods	245.85	.6244	.1590	.0919	−292.30	−168.95
		(.1771)	(.0364)	(.0428)	(151.23)	
Services	35.43	.7550	.2423	.1174	−138.03	−66.87
		(.2782)	(.1003)	(.1072)	(436.73)	

[a] Standard errors are in parentheses.

Dynamic Systems: Structural Parameters and Elasticities

Estimates of the structural parameters and elasticities for the state adjustment model are presented in table 6. There are two negative and two positive stock coefficients. This means that durable and semidurable goods with values for α_i less than zero are subject to inventory adjustment, while nondurables and services having α_i's with positive signs are subject to habit formation. In each of the cases the results seem plausible.

Estimated values for the δ_i's indicate rates of deterioration of from .10 for semidurables to .81 for nondurables. The estimated values for these structural parameters imply that habits in the case of nondurables and services deteriorate at faster rates than durable and semidurable goods depreciate. For each of the commodity groups, the short-run income coefficient κ_i is positive and the short-run price coefficient ν_i negative.

For durable and semidurable goods the short-run income elasticity exceeds the long-run income elasticity. The converse is true for the short- and long-run elasticities for the nondurable goods and services commodity groups. This result is consistent with the Houthakker and Taylor rationalizations for inventory adjustment and habit formation. The direct price elasticities of demand have the anticipated negative signs and, as expected, price elasticities for the durable goods commodity groups are higher.

An examination of the structural coefficients for the dynamic linear expenditure system in table 7 reveals that all estimated depreciation rates δ_i's are positive. In addition, they are plausible in magnitude, with larger values for nondurables (.90) and services (.87) than for durables (.30) and semidurables (.10). The higher depreciation rates for the nondurable and service groups reflect a lack of a strong persistence of habits. For durable goods, the rate of .30 implies that they are more than 90% depreciated by the end of seven years.

All of the estimated μ_i's are positive, indicating a decreasing marginal utility for each commodity. Two of the commodity groups, durables and semidurables, have negative α_i's indicating inventory adjustments. The remaining two commodity groups, nondurables and services, have positive estimated values for the α_i's and thus are subject to habit formation. In every case the "autonomous necessary consumption level" θ_i is positive, with larger values for the semidurables and nondurables than for durables and services commodity groups. The adjustment coefficients ρ_i are between zero and one in every case, indicating a partial adjustment mechanism for the state variables.

Estimated short- and long-run income elasticities are all positive. For the durables and semidurables commodity groups, the short-run income elasticities (3.13 and 1.11, respec-

Table 5. Estimates of Basic Parameters for Dynamic Linear Expenditure Model

Commodity Group	k_{i0}	k_{i1}	k_{i2}	k_{i3}
Durables	15.98	.4332	156.32	−114.72
		(.0469)[a]	(7.11)	(9.24)
Semidurables	15.38	.8618	68.77	−61.91
		(.0568)	(5.45)	(6.76)
Nondurables	146.63	.5353	88.85	−33.30
		(.0842)	(9.04)	(16.0)
Services	12.51	.6978	121.35	−47.74
		(.0300)	(13.0)	(14.62)

[a] Standard errors are in parentheses.

Table 6. Structural Coefficients and Elasticities for the State Adjustment Model

Commodity Group	θ	α	κ	ν	δ	Elasticities Income	Elasticities Price
Durable Goods	47.28	−.393	.3928	−261.85	.301	SR 3.30	−1.31
						LR 1.43	−.57
Semidurable Goods	173.44	−.065	.1728	−96.56	.103	SR 1.19	−.35
						LR .73	−.21
Nondurable Goods	372.36	.350	.1392	−255.88	.813	SR .42	−.43
						LR .74	−.76
Services	63.14	.360	.2092	−119.17	.690	SR .52	−.13
						LR 1.19	−.31

tively) are larger than the long-run income elasticities (1.09 and .71, respectively). The situation for the nondurables and services commodity groups is reversed, indicating habit formation. This effect is pronounced in the case of the services group, where the long- and short-run elasticities estimates are 1.33 and .60, respectively.

All the price elasticities have negative signs, with the compensated ones being the smaller. The uncompensated price elasticity estimates for durables (−1.44) and semidurables (−.671) are larger than those obtained from the state adjustment model. Lastly, in computing estimates, during the final iteration, the marginal utility of income, λ, declined in a continuous fashion with time. Because real income, in general, increased over the time period, this result corroborates the apparent reasonable estimates of the other structural parameters for the model.

The results in tables 6 and 7 can be compared with those in table 3. The income elasticity for the durable goods commodity group in the static systems is about 1.4. This lies between the short- and long-run estimates of the income elasticity in the dynamic models, i.e., 1.4 to 3.3 for the state adjustment model and 1.1 to 3.1 for the dynamic linear expenditure system. Estimated short- and long-run income elasticities for the semidurable goods group are, if at all, only slightly higher for the dynamic than for static systems.

The price elasticity estimates from the static models are more comparable to those generated from the state adjustment model than the dynamic linear expenditure system. This could be because the latter provides added structure ρ_i. Generally, the results demonstrate that the adjustment, habit, and inventory features of the dynamic models have more plausibly captured the behavior of consumers.[6] Values of short- and long-run, com-

[6] Additional estimates allowing for serial correlation (Berndt and Savin) in the errors for the static systems were computed. Generally, the model with autocorrelated errors produced structural parameter estimates which were more variable but elasticities implied similar to the ones presented for the static systems. Apparently persistence in consumption patterns is best accommodated by allowing for it in the systematic portion of demand models.

Table 7. Structural Coefficients and Elasticities for the Dynamic Linear Expenditure Model

Commodity	δ_i	μ_i	α_i	θ_i	ρ_i^a	γ^*_i	μ^*_i	Income Elasticity	Direct Price Elasticity Uncompensated	Direct Price Elasticity Compensated
Durables	.30696	189.12	−.4840	72.65	.79096	28.19	.15095	SR 3.13	−1.44	−1.01
								LR 1.09	−0.89	−0.74
Semidurables	.10498	70.19	−.04347	157.36	.14846	111.29	.10289	SR 1.11	−0.67	−0.51
								LR 0.71	−0.63	−0.53
Nondurables	.90953	79.56	.30435	210.04	.60518	315.67	.24590	SR 0.53	−0.41	−0.23
								LR 0.71	−0.62	−0.37
Services	.87049	99.59	.51464	16.93	.3559	41.41	.50106	SR 0.60	−0.49	−0.27
								LR 1.33	−0.97	−0.47

[a] $\rho_i = \delta_i - \alpha_i$.

pensated and uncompensated price elasticities tend to bracket those obtained for the static models.

Evaluation

In addition to the comparisons made in the previous section, the results are evaluated relative to those obtained from another commodity grouping and other studies, as well as by the forecasting potential of the models. The alternative grouping of commodities is more disaggregated. The available estimates of price and income elasticities provide a basis for evaluating the applied implications of different data bases, estimation methods, demand systems, and commodity groups. Finally, the forecasts within and outside of the sample period are made using the two dynamic models. These two dynamic models were selected for the forecasting exercise because the structural parameter estimates and elasticities reviewed in the previous section compared favorably to those from the static systems.

Nine Commodity Groups

Price and income elasticity estimates obtained by applying two of the static demand systems and the double log model to the Canadian data aggregated to nine commodity groups are contained in table 8.[7] The same exercise was attempted for the indirect addilog and dynamic demand systems. Unfortunately, the solutions were erratic or the models failed to converge, suggesting problems of multicollinearity or with the capacity of our computer programs for larger models. The double log estimates obtained without forcing the income elasticities to one are included to provide a contrast with the more theoretically consistent Rotterdam and linear expenditure systems. Comparative comments are confined to the Rotterdam and linear expenditure systems.

In examining table 8, attention is first drawn to the pattern of the estimated income elasticities. These results show that as for the four commodity groups, all income commodities are positive. For the Rotterdam and linear expenditure systems, commodity groups with an income elasticity less than unity are food, tobacco and alcoholic beverages, clothing, and personal goods and services. Consumption of these goods should tend to remain more stable for differing income levels. The results for food, in particular, are worth noting, because Engel's law concerning the decreasing share of expenditures on food with income increases is confirmed. Income elasticity estimates for housing and furniture are close to one. These commodity groups may, therefore, be viewed as luxuries, albeit moderate ones. The highest estimated income elasticities were obtained for transportation and recreation. As subsequently shown, for transportation this result is different than that obtained for the United States. Also, recall that for the commodity groups, transportation and recreation are highly influenced by durable goods purchases, a type of consumption behavior not especially well modeled by the static assumptions which underlie the results presented in table 8.

In comparing the Rotterdam model income elasticities to those of the linear expenditure model, some differences are observed. For example, income elasticities for food, clothing, furniture, and transportation are slightly lower for the linear expenditure system than in the Rotterdam model. Income elasticities for tobacco and alcoholic beverages and drugs and sundries are almost identical in both models. This is in contrast to the results from the four-commodity case which showed the Rotterdam estimates with one exception uniformly higher.

Examination of the direct uncompensated price elasticity estimates in table 8 shows that all have the expected negative sign. Also, with five exceptions, the estimates have magnitudes which indicate an inelastic price response. The exception in the case of linear expenditure system is the recreation and entertainment commodity group where the required consumption level γ was estimated as negative. For the Rotterdam model the estimated uncompensated price elasticities are 1.00 for transportation and communication and 1.09 for recreation and entertainment. The larger differences between the uncompensated price elasticity estimates for the Rotterdam

[7] With only two exceptions, the groups of commodities and services are the same as used by Statistics Canada. The two exceptions are: (1) under the heading "Medical Care and Health Services," the components, medical care, hospital care, and other medical care expenses have been deleted. This deletion became necessary because of discontinuities in the series from 1961 due to the transfer of expenditures for non-profit hospitals from the personal sector to government and because, as various provincial administered medical care plans have come into effect beginning in 1962 and extending to 1971, personal expenditures on medical services have shifted to current government expenditures from goods and services; (2) the second is deletion of "Net Expenditure Abroad." Since this is a residual item consisting of the balance of tourist revenue, it should not significantly alter the results.

Table 8. Comparison of Price and Income Elasticities Estimated for Different Static Models

		Income Elasticity			Direct Price Elasticity					
					Uncompensated			Compensated		
Commodity Group	Expenditure Share	Rotterdam	Linear Expenditure	Double-Log	Rotterdam	Linear Expenditure	Double-Log	Rotterdam	Linear Expenditure	Double-Log
Food	0.1845	0.55	0.39	0.86	−0.42	−0.30	−0.20	−0.32	−0.23	−0.04
Tobacco and Alcoholic Beverages	0.0691	0.80	0.79	0.37	−0.54	−0.52	−0.63	−0.49	−0.47	−0.60
Clothing	0.0904	0.74	0.63	0.69	−0.52	−0.43	−0.42	−0.45	−0.37	−0.35
Gross Rent, Fuel and Power	0.1838	1.04	1.30	0.65	−0.74	−0.86	−0.91	−0.54	−0.62	−0.79
Furniture, Furnishings, Household Equipment and Operations	0.1072	1.05	0.68	0.97	−0.72	−0.47	−0.48	−0.60	−0.39	−0.37
Drugs and Sundries	0.0137	1.20	1.28	1.44	−0.78	−0.81	−1.02	−0.77	−0.79	−1.00
Transportation and Communication	0.1425	1.55	1.25	2.38	−1.00	−0.82	−1.88	−0.78	−0.64	−1.54
Recreation, Entertainment, Educational and Cultural Services	0.0744	1.70	2.18	1.62	−1.09	−1.30	−0.38	−0.96	−1.14	−0.26
Personal Goods and Services	0.1344	1.76	1.07	0.63	−0.55	−0.71	−0.10	−0.44	−0.57	−0.01

and linear expenditure models are for the furniture, furnishings, household equipment and operations, and the personal goods and services groups.

Generally, the estimates from the nine commodity groups appear supportive of the results and associated observations made for the application of the static models to the four commodity groups. The static models even at lower levels of disaggregation do not produce results which are as satisfactory for commodity groups made up of durable goods, as do the dynamic models. For example, in the cases of the furniture, furnishings, household equipment and operation group and the transportation group, the income and price elasticities obtained show comparatively large differences between the Rotterdam and linear expenditure system estimates and those for durable goods obtained when the dynamic models were applied for four commodity groups. Although the overlap in classes is not complete, the stability of the estimates between the dynamic systems and their discrepancies between the static models would suggest some improvement resulted from the more flexible structures.

Estimates From Other Studies

Comparisons of the estimates for the four and nine commodity cases to those from other studies must be made with caution since the latter involve different models, data bases, estimation methods, and commodity groups. Results of the studies, however, can be evaluated in relation to their implications for policy purposes. For the present evaluation, results for income and price elasticities from several studies using Canadian and United States data have been assembled in table 9. (Other studies using Canadian data include Carlevaro, Goldberger and Gameltsos, Oksanen and Spencer, and Schweitzer.) The table includes a citation and information on the country, the time period of application, the demand system employed, the commodity groups, and the elasticity estimates.

The comparisons afforded by the information in tables 3, 6, 7, 8, and 9 are obviously numerous. The income elasticity estimates for food from the present analysis and among the other studies are quite similar. Food is income inelastic with a coefficient in the range .31 to .64. In the four commodity group models, food

Table 9. Comparison of Price and Income Elasticity Estimates with Other Studies

Study	Time Period/ Country	Demand System[a]	Commodity Group	Elasticity Price	Elasticity Income
Powell (1965)	1949–1963/ Canada	Additive Preference	Food	−0.46	0.58
			Tobacco & Alcoholic Beverages	−0.54	0.79
			Clothing	−0.52	0.74
			Shelter	−0.38	0.51
			Household Expenses	−1.28	2.13
			Transportation	−1.37	2.32
			Personal, Medical	0.05	−0.07
			Miscellaneous	−0.67	0.97
Wales	1947–1968/ Canada	LES	Food	−0.27[b]	0.31[b]
				(−0.39)[c]	(0.86)[c]
			Clothing	−0.24	0.33
				(−0.31)	(0.95)
			Shelter	−0.81	1.14
				(−0.20)	(0.42)
			Miscellaneous	−1.02	1.67
				(−0.71)	(1.52)
McIntosh	1949–1968/ Canada	LES	Food	−0.26	0.45
			Clothing	−0.22	0.51
			Housing	−0.67	1.30
			Transportation & Communication	−0.59	1.41
			Recreation, Education & Entertainment	−0.58	1.19
			Health	0.35	−0.69
			Miscellaneous	−0.70	1.39
Berndt, Darrough & Diewert	1952–1971/ Canada	TLOG	Durables	−1.18	1.59
			Non-Durables & Semi-Durables	−0.68	.35
			Services	−0.42	1.61
Hassan, Johnson & Finley	1929–1969/ USA	Rotterdam	Durable Goods	−0.86	2.43
			Food	−0.33	0.64
			Clothing & Shoes	−0.44	1.13
			Gasoline & Oil	−0.28	0.79
			Other Non-Durable Goods	−0.47	1.15
			Housing	−0.20	0.46
			Household Operation	−0.33	0.89
			Transportation	−0.36	1.04
			Other Services	−0.32	0.71
Weiserbs (Phlips (1974))	1929–1970/ USA	LES-D	Automobiles & Parts	−2.13[d]	7.57[d]
				(−1.35)[e]	(1.65)[e]
			Furniture & Household Equipment	−0.89	2.35
				(−0.90)	(0.92)
			Other Durable Goods	−0.48	1.27
				(−1.50)	(1.88)
			Food & Beverages	−0.30	0.53
				(−0.53)	(0.58)
			Clothing & Shoes	−0.47	1.11
				(−0.97)	(1.04)
			Gasoline & Oil	−0.15	0.36
				(−1.17)	(1.76)
			Other Non-Durable Goods	−0.33	0.76
				(−0.92)	(1.21)
			Housing	−0.12	0.24
				(−1.43)	(3.49)
			Household Operation	−0.24	0.58
				(−1.38)	(2.23)
			Transportation	−0.31	0.80
				(−0.87)	(1.03)
			Other Services	−0.27	0.56
				(0.85)	(−0.99)
Lluch & Williams	1930–1972/ USA	LES	Food	−0.28	0.41
			Clothing	−0.48	0.90
			Housing	−0.61	1.13
			Durables	−0.83	1.61
			Other	−0.74	1.13

[a] LES denotes linear expenditure system. LES-D indicates linear expenditure system-dynamic. TLOC denotes translog reciprocal indirect utility function.
[b] Linear expenditure system "static."
[c] Linear expenditure system "habit formation."
[d] Short run estimates.
[e] Long run estimates.

is in the class of nondurables. Our estimates of income elasticities for this nondurables commodity group show the short- and long-run income elasticities ranging from about .4 to .7, the latter being the long-run estimate. This compares to an income estimate of .68 obtained for a non- and semidurables class by Berndt, Darrough, and Diewert.

In the case of clothing, our income elasticity estimates are consistent with those of Powell, Wales, and McIntosh for Canada. However, they are lower than those published by Hassan, Johnson, and Finley; Weiserbs; and Lluch and Williams for the United States. The semidurables in the four commodity group models have somewhat higher income elasticities than those reported for clothing. This is true even of the state adjustment and dynamic linear expenditure models, which suggest a range of .7 to 1.2 for short- and long-run income elasticities for semi-durables.

For both shelter and transportation, the estimates from the present analysis are in general agreement with those in table 9. Our results and those in table 9 show a systematic difference between the United States and Canada in income elasticity for transportation. This may be due to subsidies in the United States and the excise tax in Canada. On a more general level, the durable goods group estimates in table 9 and our own estimates for this commodity group indicate a similar income elasticity. Again, the flexibility of the dynamic models is suggested by the fact that the income elasticity estimates for durables in tables 6 and 7 bound most of those reported in table 9.

Price elasticity estimates seem to be roughly similar for food, clothing, and durable goods. This is especially true of those estimates obtained from the linear expenditure system and the indirect addilog models. In the case of durable goods, elasticities estimated from the static models lie between those for durable goods from the two dynamic models. Finally, for shelter, the own price elasticities differ from those in table 9. However, the source of the difference appears due more to the variable results obtained in other studies than as a systematic effect in our data or models.

Forecasting Performance

As a last evaluative exercise, the forecasts from the two dynamic models are examined. Data for estimating the models were for 1947–1972. The outside sample data used (1973, 1974) are revised series obtained from Statistics Canada, and the revisions were substantial for the services group. These revised values were used without adjustment for simulating the model, perhaps causing some discrepancy. The model was not reestimated since the revised data series is presently not of sufficient length.

Forecasts or simulations were calculated using actual revised initial values of the lagged endogenous variables. Simulated values were used after the models were initialized at the first period, and there was no calibration to insure better fits. Most of the turning points were properly reflected, and there were few major discrepancies in the levels of the actual and simulated expenditures. These observations are borne out in table 10, which contains the root mean square error (absolute and percentage) for the models in and outside the sample period. Generally, the within and outside sample period results suggest the same conclusions. The dynamic linear expenditure system produces the better fit. Errors are largest for services and smallest for nondurable goods outside the sample period, but largest for durables within the sample period. The former discrepancy could be caused by the revisions in the data series.

Table 10. Evaluative Statistics for the Simulation of the Dynamic Models

	State Adjustment Model				Linear Expenditure-Dynamic			
	RMS (Error)		RMS (Percent Error)		RMS (Error)		RMS (Percent Error)	
Commodity Group	47–72	73–74	47–72	73–74	47–72	73–74	47–72	73–74
Durable Goods	8.56[a]	28.60[b]	4.24	5.86	6.50	10.14	2.93	2.13
Semidurable Goods	3.87	18.03	1.25	4.34	2.87	12.01	1.03	2.88
Nondurable Goods	7.00	11.07	1.03	1.24	7.31	13.11	1.05	1.46
Services	15.21	42.41	1.89	3.72	14.98	42.62	1.67	3.73

[a] Inside the sample period.
[b] Outside the sample period and with unincorporated revisions of the services series.

Conclusion

Generally, there is a substantial degree of similarity between the estimates obtained in this analysis, even between static and dynamic models. The static models, except for the double log, produced estimates which had similar implications and compared favorably with those summarized from other studies when the latter were themselves not erratic. Of the two dynamic models, the linear expenditure system performed better by comparison to results from other studies and on the basis of the within and outside sample simulations. This improved performance is possibly a result of the more flexible adjustment mechanism that the linear expenditure system incorporates. Generally, the plausible adjustment implications and the estimated long-run price effects compared to those for the static models provide an empirical impetus for attempting to extend models of the structure of consumer behavior to more dynamic settings.

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Food Distribution and Food Stamp Program Effects on Food Consumption and Nutritional "Achievement" of Low Income Persons in Kern County, California

Sylvia Lane

Participants in the U.S. Department of Agriculture's Food Distribution Program received more food than they would have purchased with food stamps in the market. These participants had slightly higher achievement ratios for some specific nutrients, such as protein, iron, and thiamine, than did nonparticipants. Food stamp recipients also had somewhat similar gains in nutrients, while spending a lower percentage of money income on food than nonparticipants.

Key words: food distribution program, food stamps, nutrition, nutritional effects of food programs.

Both the Food Distribution and Food Stamp programs were intended, in part, to improve diets of low income households ("Agricultural Act of 1949" and the "Food Stamp Act of 1964"). Whether or not the programs result in nutritional benefits and which of the two is the more effective remain controversial questions. Under the Food Distribution Program, food is made available to participating households (California State Department of Education). Under the Food Stamp Program, stamps are sold to participating households at less than their face value (State of California). The stamps may then be used like money for the purchase of food at cooperating retail establishments. The difference between the amount paid for the stamps, which depends on income less deductions for some household expenses, and the face value of the stamps received by the household, which is the same for all households of equal size, is the amount of publicly funded food-aid, termed "bonus stamps."[1]

The questions addressed in this study are as follows: First, did the programs result in an increase in food consumption and, if so, in improved levels of nutrition? Second, if they did, which of the two programs was the more effective? The findings have implications for the policy debate on the form of food-aid and improved nutrition (see U.S. Congress, 1973).

The discussion of the study is divided into six sections. Survey procedures are described in the first section, the nutritional measures used, in the second. Sample household expenditures on food and food stamps, the value of food purchased and received by these households, program effects on these variables along with some implications thereof, and program preferences of sample households are discussed in the third. The two following sections contain the description of the nutritional effects of the program, an explanation of the findings and their implications, and the last, a summary and conclusions.

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[1] On the average, households participating in the Food Stamp Program throughout the United States in 1972 paid about 45¢ for each dollar's worth of food stamps. (Estimate from Acting Director of Food Stamp Program, Western Region, Oct. 1973.)

Survey Procedures

Kern County, located in south central California, was selected as the location for this study because the Food Stamp Program replaced a Food Distribution Program in the county in September 1972. This afforded the opportunity to study program functioning in a relatively stable population at a single location in adjacent time periods.

Five hundred ninety-nine households composed of 2,813 persons were surveyed in July and August 1972, during the operation of the Food Distribution Program in Kern County. A sample of 299 was selected by first randomly contacting recipients of U.S. Department of Agriculture distributed foods at distribution points in Bakersfield and Arvin, in order to determine their eligibility and willingness to cooperate. A sample of 300 low-income households meeting program eligibility requirements but not receiving distributed foods was located by interviewers inquiring at dwellings closely adjacent to those of the participants who had been contacted at the distribution points.

After the Food Distribution Program was replaced by the Food Stamp Program, 329 households composed of 1,599 persons were surveyed during January and February 1973. An attempt was made to interview the 300 low-income households previously surveyed, but only 204 could be included. The remainder of the 329 households contacted in January and February 1973 were low-income households meeting program eligibility requirements living closely adjacent to the recontacts. This second survey was made in the fifth month after the program changeover to allow participants to adjust to the new program.

The sample contained similar-sized groups of eligible participating and nonparticipating low-income Afro-, Mexican-, and Anglo-American households, to assure that impacts of program participation upon nutritional achievement levels of the different groups would be reflected accurately in the sample means.[2]

The survey questionnaire was designed to elicit data on economic and social characteristics and food consumption of interviewed households. The questionnaire used by National Analysts, Incorporated, for the 1965–66 "Survey of Food Consumption in the United States" served as a model for the format of the section on food consumed, but respondents were questioned concerning food consumed at home in the twenty-four hours prior to the interview, rather than food consumed in the preceding seven days. Studies of food consumption or diet survey methodology consulted) (Linusson, Sanjur, Erickson; Madden, Goodman, Guthrie; Pekkarian; Wilson et al.; Young et al.), with one exception (Madden, Goodman, Guthrie) indicated no significant differences existed between the level of accuracy achieved by the seven-day as opposed to the 24-hour recall method and found, since abnormal consumption effects are usually balanced out, the 24-hour recall method could be used for large samples in group comparisons but not for evaluating the nutrient levels of individuals.

Nutritional Measures

Nine components found to be essential for adequate nutrition: calories, protein, calcium, vitamins A and C, iron, niacin, riboflavin, and thiamine, were considered in the analysis (USDA, 1963). Nutrient Achievement Ratios (NAR's), used as comparative measures, expressed the amount of a nutrient consumed by members of a household as a percentage of the amount recommended for that household as established by the Recommended Daily Dietary Allowances which take sex and age of persons into consideration.[3] These allowances are not average nor minimum requirements. They are estimated to exceed the requirements of most individuals and thus assure that virtually all persons consuming at these levels will have nutritionally adequate diets. NAR's were truncated at 100%.

Expenditure on Food and Food Stamps, Value of Food Purchased and Received, and Income

Table 1 contains data on expenditures on food and food stamps, value of food purchased and

[2] Nutritional "achievement" refers to the extent to which intake of various nutrients meets the Recommended Dietary Allowance established by the Food and Nutrition Board of the National Academy of Sciences and the National Research Council (as revised in 1973).

[3] Losses of nutrients due to cooking and storage of food were assumed to be equal for all households so that comparisons would not be affected. Home-prepared food consumed net of leftovers, food fed to pets, or refuse was analyzed to ascertain its nutritional composition.

Table 1. Value of Food Purchased and Received, Food Expenditure and Income, by Household, Per Person, Food Distribution and Food Stamp Program Participants and Nonparticipant Households, Kern County, California, 1972–1973

	July–August 1972 Interviews			January–February 1973 Interviews			Continuing Sample[a]		
	Food Distribution Program Participants	Non-Participant Households	Difference	Food Stamp Program Participants	Non-Participant Households	Difference	Food Stamp Program Participants	Food Distribution Program Participants	Difference
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Number of persons	1,500	1,313		759	800		394	417	
Number of households	299	300		151	178		74	74	
Average household size	5.02	4.38	.64[g]	5.03	4.49	.54[g]	5.32	5.64	.32
Income (dollars per month)[b]									
Money income	71.72	91.00	−19.28[g]	72.86	80.20	−7.34[g]	72.80[h]	69.61	3.19
Income in kind[c]	20.60	1.37	19.23	11.46	2.40	9.06	8.09	21.39	−13.30
Total income[d]	92.32	92.37	− .05	84.32	82.60	1.72	80.89[h]	91.00	10.11
Value of food (dollars per month)									
Expenditure on food[e]	24.49	30.58		6.26	26.42		6.67[h] }	23.24	−3.80
Expenditure on stamps				12.28			12.77[h] }		
Food aid benefit	16.61[f]	0		8.69	0		8.05[h] }	16.61 }	−10.30
Other food in kind[f]	3.99	1.37		2.77	2.40		3.04[h] }	4.78 }	
Total value of food purchased & received	45.09	31.95	13.14[g]	30.00	28.82	1.18	30.53[h]	44.63	−14.10[g]
Percent of money income for									
Expenditure on food	34.2	33.6		8.6	32.9		9.2 }	33.4	
Expenditure on stamps				16.9		−7.4	17.5 }		6.7
Total value of food as a percentage of total income (percent)	48.8	34.6	14.2	35.6	34.9	.7	37.7	49.0	11.3

[a] Continuing sample households participated in both the Food Distribution and Food Stamp programs. However size and composition of households changed in some cases in the six months between interview periods.

[b] "Income," "expenditure," "food-aid benefit," and "other food in kind" values in this table are sample means of household means divided by number of persons in household.

[c] Income in kind includes estimated dollar benefit from food-aid program plus the retail value of all gifts, payments in kind and home-produced food.

[d] The sum of money income and income in kind including food aid.

[e] Out of pocket cash expenditures for food prepared at home exclusive of purchase requirement for food stamps. Dollar estimates appearing in table are all mean values. Sample means in this table were derived from respondents' replies to questions on amounts spent in a month on food and food stamps; dollar value of gifts, donated foods and income in kind per month, and monthly income.

[f] 70.8 percent of full retail value of distributed foods available each month were accepted, on the average, by all Kern County participants. However, this group apparently accepted the entire package offered.

[g] Difference between participants and nonparticipants statistically significant at the 95 percent level (Wilcoxen Signed Ranks Test).

[h] Expenditures on food would have been $6.39 if adjusted for changes in food prices from July 1972 to January 1973. Adjusted total expenditures on food and food stamps would have been $18.63 and the adjusted value of food available would have been $29.31. Adjusted mean money income adjusted for changes in the consumer price index would have equaled $71.49 and adjusted total mean income would have equaled $79.43.

received, and both money and real income, i.e., income including distributed foods and other nonpurchased food per person, for the survey month, for program participant and nonparticipant sample households. Participating households in both programs in this sample were larger and had less money income per person than nonparticipating households. Differences in household size and money income per person between participant and nonparticipant sample sets were both statistically significant.[4]

Sample means from table 1 were used in calculating the estimates of program effects on food consumption, or more specifically food purchased and received and therefore available for consumption. Expenditure on food per person as a percentage of money income per person (average propensity of consumption for food) was 34.2% for participant households in the Food Distribution Program and 33.6% for nonparticipants. For the Food Stamp Program participant households, the percentages were 8.6 for food purchased for cash and 16.9 for food stamps or 25.5. For the Food Stamp Program nonparticipant households, the percentage was 32.9. Households participating in the Food Distribution Program, on the average, received distributed foods worth $16.61 at retail prices and had $17.00 more food available. Had the Food Distribution Program participant households spent the same proportion of money income per person as the nonparticipant households, they would have spent $24.10 per person in the survey month and had $28.09 in food purchased and received per person including other food in kind ($24.10 + 3.99), on the average. They actually had $45.09 available, but they spent $24.49 rather than $24.10 (column 1, table 1). Thus, on the average, additional food available because of program participation was $17.00 ($45.09–$28.09). The $17.00 less the additional 39¢ spent on food equaled $16.61.

Without the program, if Food Stamp Program participant households spent the same proportion of money income as nonparticipant households, they would have had, on the average, food valued at $26.74 ($23.97 + 2.77) per person including other food in kind. They had food valued at $30.00 (column 4, table 1), an increase of about $3.26 per person, or 38% of the $8.69 received in bonus stamps. This is comparable to the marginal propensity to consume food of 30% reported by West and Price (p. 728).

The continuing sample that participated in both programs spent 33.4% on food when participating in the Food Distribution Program and 26.7% when participating in the Food Stamp Program. They had $14.10 less food available, including other food in kind, when participating in the Food Stamp Program when the food aid benefit was $8.56 less (columns 7, 8, and 4, table 1).

Both programs resulted in increasing the value of food available for participants' consumption. The analysis further suggests the additional income provided by the Food Stamp Program, in the form of bonus stamps, made it possible for participating households to reduce the percentage of money income spent on food. However, part of the purchasing power that became available because the household received bonus stamps was spent for food. That the percentage of money income spend on food by Food Distribution Program participants was slightly higher than that for nonparticipants in this sample suggested many participants may not have received "preferred" foods.

In fact, when surveyed households who had participated in both programs (although not necessarily during the period of this study) were asked which program they preferred, they indicated a preference for the Food Stamp Program by a ratio of 4.7 to 1. A wider choice among foods was cited by 75% of those who preferred food stamps. "Less waste with food stamps" was the second most important reason being cited by 9.3%. Nineteen of the twenty-three households who preferred the Food Distribution Program did so primarily because they found distributed foods "more economic for their families."

Analysis of Nutritional Indicators

It had been hypothesized programs would affect nutrition through their effect on value of food available, the only policy variable which the programs analyzed materially affected.[5] The relationship between nutritional achieve-

[4] The two samples were not drawn independently. For example, the 74 households in the continuing sample were the same households and the households with and without the program were also the same households and cannot be construed as being independent samples. Therefore, nonparametric tests, i.e., Wilcoxen Signed Ranks Tests, were used to evaluate the differences between means in table 1. In table 3, t-tests were used, but the lack of independence of the samples means they must be interpreted with caution. However, Wilcoxen Signed Ranks Tests performed on the continuing sample gave the same results.

[5] Some attempts to provide some nutrition education existed under both programs, but there was no required educational com-

Table 2. Constants, Coefficients, and Standard Errors of Coefficients from Tobit Analysis of Relationship Between Value of Food Available per Nutritionally Equivalent Person and Household Nutritional Achievement Ratios, Food Distribution and Food Stamp Program Participant and Nonparticipant Households, Kern County, California, 1972–73

	July–August 1972 Interviews								
	Food Distribution Program Participant Households			Nonparticipant Households			Continuing Sample[b]		
	α	β	Standard error[a]	α	β	Standard error[a]	α	β	Standard error[a]
1) Calories	.88521	.00386[c]	.00096	.86569	.00590[c]	.00157	.77664	.00693[c]	.00266
2) Protein	1.59142	.00196	.00180	1.94810	.00532	.00526	1.83450	.00369	.00543
3) Calcium	.68276	.00750[c]	.00144	.79580	.00554[c]	.00199	.73800	.00804[c]	.00300
4) Iron	.88567	.00683[c]	.00160	.88517	.00995[c]	.00267	.89975	.00612	.00321
5) Vitamin A	.76250	.00297[c]	.00095	.66265	.00801[c]	.00201	.88074	.00060	.00145
6) Thiamine	.90216	.00458[c]	.00111	.98132	.00232	.00147	.87289	.00493	.00228
7) Riboflavin	1.07973	.00534[c]	.00150	.11013	.00750[c]	.00241	1.12795	.00498	.00313
8) Niacin	1.86558	.00374	.00321	.29710	−.00528	.00644	1.44164	.00488	.00525
9) Vitamin C	.82077	.00415[c]	.00165	.74512	.01381[c]	.00359	.77878	.00319	.00247
	January–February 1973 Interviews								
	Food Stamp Program Participant Households			Nonparticipant Households			Continuing Sample[b]		
	α	β	Standard error[a]	α	β	Standard error[a]	α	β	Standard error[a]
1) Calories	.87746	.00401	.00233	.81479	.00472[c]	.00195	.77688	.00558	.00343
2) Protein	2.06121	.01678	.01473	1.48352	.00149	.00350	2.13832	.01195	.01970
3) Calcium	.78313	.00899[c]	.00398	.77362	.00815[c]	.00328	.56665	.01425[c]	.00608
4) Iron	.97622	.00432	.00416	.89378	.00973[c]	.00378	.92105	.00228	.00610
5) Vitamin A	.56132	.00784[c]	.00283	.82925	.00173	.00245	.29892	.01141[c]	.00352
6) Thiamine	1.06631	.00212	.00270	.95640	.00207	.00206	.98863	.00319	.00391
7) Riboflavin	1.06796	.00981[c]	.00444	1.07366	.00495	.00266	.84099	.01362[c]	.00643
8) Niacin	2.24633	−.00011	.00986	2.24346	.00217	.00787	2.28785	.00068	.01407
9) Vitamin C	1.15385	−.00412	.00564	1.13360	−.00185	.00373	1.02205	.00005	.00894

[a] Standard Error of β coefficient.
[b] The continuing sample households participated in both programs. They were the only sample households interviewed twice. They constituted 25% of the food distribution program participant sample and 49% of the food stamp program participant sample.
[c] Significantly different from 0 at the 95% level (a two standard error deviation does not include a "zero" mean). The University of Rochester's limited dependent variable regression program was used in this analysis.

ment ratios and the dollar value of food purchased and received (food consumption according to the West and Price definition, p. 723) per nutritionally equivalent person for program participant and nonparticipant households was analyzed using Tobit analysis.[6] Tobit analysis is a hybrid regression technique permitting the use of a dependent variable with a lower (or upper) limit (Tobin, pp. 24–36).[7] Nonnormalized coefficients and standard errors from the Tobit analysis of household nutritional achievement ratios per nutritionally equivalent person for each of the participant groups appear in table 2. The equation estimated was $NAR = \alpha + \beta(VFA)$,

ponent in either program during the study period. There is no data on the effectiveness of the educational effort connected with the program.

[6] The allowance set for each of the nine nutrients in the Recommended Daily Dietary Allowances for nine age-sex groups and pregnant and lactating females may be expressed as a proportion of the allowance set for a reference person—an adult male 25–50 years of age.

[7] "Account should be taken of the concentration of observations at the limiting value when estimating statistically the relationship of a limited variable to other variables and in testing hypotheses about the relationship. An explanatory variable in such a relationship may be expected to influence both the probability of limit responses and the size of nonlimit responses. If only the probability of limit and nonlimit responses, without regard for the value of nonlimit responses were to be explained, probit analysis provides a suitable statistical model. But it is inefficient to discard information on the value of the dependent variable when it is available. If only the value of the variable were to be explained, if there were no concentration of observations at a limit, multiple regression would be an appropriate statistical technique. But when there is such concentration, the assumptions of the multiple regression model are not realized. According to that model, it should be possible to have values of the explanatory variables for which the expected value of the dependent variable is its limiting value; and from this expected value, as from other expected values, it should be possible to have negative as well as positive deviations. A hybrid of probit analysis and multiple regression seems to be called for. This is Tobit analysis," (Tobin, p. 25).

where *NAR* was the nutritional achievement ratio for the household and *VFA*, the value of food available, was value of food purchased and received per nutritionally equivalent person in the household.

Coefficients for calories, calcium, iron, vitamin A, thiamine, riboflavin, and vitamin C are significant at the 95% level for program participant households under the Food Distribution Program. Coefficients for the same nutrients, except for thiamine, are also significant for nonparticipant households under the Food Distribution Program. Thus, an additional value of food available apparently affected nutritional achievement for both groups.

Coefficients for calcium, vitamin A, and riboflavin were significant for Food Stamp Program participant households and calories, calcium, and iron for the nonparticipant households interviewed when the Food Stamp Program was in effect. For the continuing sample the value of food available was associated with significantly higher ratios for calories and calcium while they were under the Food Distribution Program and significantly higher ratios for calcium, vitamin A, and riboflavin while they were under the Food Stamp Program.

Program Participation Effects

Estimates of mean nutritional achievement ratios for each nutrient associated with the value of food purchased and received per nutritionally equivalent person for households in the various groups in the program appear in table 3. To estimate the mean nutritional achievement ratios for program participants, had they not participated, the *NAR*'s were computed from the equation $NAR = \alpha + \beta (VFA)$ for the two participant groups for each nutrient. Values of α and β used appear in table 2. The appropriate *VFA* was estimated by multiplying the participant household's money income by the percentage of money income spent on food by nonparticipant households and adding the food-in-kind. The values appearing in the table are the averages of the *NAR*'s so obtained for each nutrient for the two groups (table 3).

Under the Food Distribution Program, the estimates suggest participant households' means for all nutrients examined, except niacin and iron, would have been significantly lower without the program. There are also significant differences between the means for protein, iron, vitamin A, thiamine, and vitamin C between participant and nonparticipant households. Nonparticipant households have lower ratios for protein, iron, and thiamine and higher ratios for vitamin A and vitamin C.

Under the Food Stamp Program the estimates suggest participant households' ratios for protein, calcium, vitamin A, and riboflavin would have been significantly lower without the program. Ratios for vitamin C would have been higher. Nonparticipants had significantly lower ratios for calories, protein, calcium, iron, thiamine, and riboflavin. Ratios were higher for vitamin C. Continuing sample households had significantly lower ratios for calories, calcium, iron, vitamin A, and riboflavin and a significantly higher ratio for vitamin C when they were under the Food Stamp Program as opposed to the Food Distribution Program.

Differences between participant and nonparticipant households may be due to the fact that nonparticipants were higher income and smaller households (table 1). Differences for the continuing sample may be due to the difference in the seasonal diet or different diets because of the composition of the "package" of distributed foods and the greater choice attainable under the Food Stamp Program. Differences between the ratios for the same participating households with and without the program contribution may also be ascribable in some part to the quantity and kinds of food made available under the Food Distribution Program and the additional quantity of and greater choices among foods made available to the households under the Food Stamp Program, the assumptions made, or the limitations of the method of estimation. However, all differences are small.

Summary and Conclusions

Households in this study participating in the Food Distribution Program spent about the same percentage on food as nonparticipating households. Those who participated in the Food Stamp Program spent a lower percentage of money income per month per person on food than nonparticipating households. (The approximately 32.00% of money income per person, on the average, spent by households other than the Food Stamp Program partici-

Table 3. Mean Values Nutritional Achievement Ratios

	Food Distribution Program			Food Stamp Program			Continuous Sample	
	Participants			Participants				
	With program	Without program	Nonparticipants	With program	Without program	Nonparticipants	Under Food Distribution Program	Under Food Stamp Program
	Mean of VFA = 45.09	Mean of VFA = 28.48	Mean of VFA = 31.95	Mean of VFA = 30.00	Mean of VFA = 21.31	Mean of VFA = 28.82	Mean of VFA = 44.63	Mean of VFA = 30.53
1) Calories	.87	.84[b]	.87	.87	.87	.83[b]	.87	.84[b]
	(.01209)	(.00178)	(.01207)	(.01530)	(.00236)	(.01687)	(.02458)	(.02464)
2) Protein	.98	.97[b]	.97[b]	.99	.98[b]	.97[b]	.98	.98
	(.00573)	(.00019)	(.00710)	(.00765)	(.00063)	(.00915)	(.01127)	(.01550)
3) Calcium	.79	.77[b]	.79	.84	.82[b]	.78[b]	.84	.79[b]
	(.01619)	(.00310)	(.01565)	(.01945)	(.00364)	(.02166)	(.02674)	(.02997)
4) Iron	.88	.88	.87[b]	.87	.87	.85[b]	.86	.83[b]
	(.01186)	(.00187)	(.01264)	(.01611)	(.00156)	(.01732)	(.02615)	(.02659)
5) Vitamin A	.76	.72[b]	.77[b]	.75	.73[b]	.73[b]	.74	.69[b]
	(.01724)	(.00170)	(.01732)	(.02286)	(.00561)	(.02286)	(.03438)	(.03425)
6) Thiamine	.89	.85[b]	.86[b]	.91	.91	.85[b]	.89	.89
	(.01128)	(.00189)	(.01236)	(.01310)	(.00094)	(.01649)	(.02176)	(.02139)
7) Riboflavin	.93	.90[b]	.93	.95	.94[b]	.91[b]	.94	.93[b]
	(.00925)	(.00139)	(.00970)	(.01025)	(.00196)	(.01304)	(.01689)	(.01898)
8) Niacin	.99	.99	.99	.99	.99	.99	.99	.99
	(.00307)	(.00015)	(.00410)	(.00423)	(.00001)	(.00615)	(.00754)	(.00853)
9) Vitamin C	.74	.71[b]	.78[b]	.75	.77[b]	.78[b]	.72	.74[b]
	(.01955)	(.00158)	(.01888)	(.02661)	(.00196)	(.02369)	(.03934)	(.04060)

Note: Sample means are of nutritional achievement ratios[a] per nutritionally equivalent person for food distribution and food stamp program participant and nonparticipant households, Kern County, California, 1972–73.

[a] The value of food purchased and received that participating households would have had without the program was estimated by subtracting the program contribution for each household. Constants and coefficients (table 2) computed for program participants with the program contributions were then used to estimate the nutritional achievement ratios of the households (per nutritionally equivalent person) without the program. The mean of these values for each nutrient for each participant group appears in the table.

[b] Significant at the 95% level or above from mean of participants with program for Food Distribution and Food Stamp samples and from mean when under Food Distribution for continuing sample (see footnote 4).

pant household is similar to the approximately 32.25% spent, on the average, throughout the U.S. by households in this income group [$4,000 to $5,000] in 1965 [USDA 1969, p. 7].) Interviewed participating households in both programs had more food per person available than nonparticipant households.

The comparisons suggest Food Distribution Program participants were receiving more food than they would have purchased in the market with money or stamps. The lower percentage of money income spent by Food Stamp Program participants as compared to Food Distribution Program participants suggests Food Stamp Program participants were being given the means of buying preferred foods. A large majority of sample members who had participated in both programs preferred the Food Stamp Program. The main reason for their preference was "a wider choice among foods."

The programs apparently affect nutrition through increasing the amount of food available to participants and through increasing real income, part of which was spent on additional food. The value of food available does appear to affect some nutrients, but the effect is small; and the results cannot be generalized on the basis of the sample in this study alone. Food Distribution Program participant households had higher mean ratios for protein, iron, and thiamine than nonparticipant households and lower ratios for vitamins A and C per nutritionally equivalent person. For the participating households the data suggests mean ratios for all nutrients examined except iron and niacin would have been lower without the program. Food Stamp Program nonparticipant households had lower mean ratios than participant households for calories, protein, calcium, iron, vitamin A, thiamine, and riboflavin per nutritionally equivalent person. Ratios were higher for vitamin C. The data also suggests Food Stamp Program participant mean household ratios for protein, calcium, vitamin A, and riboflavin would have been lower without the program and ratios for vitamin C higher. For the continuing sample calories, calcium, iron, vitamin A, and riboflavin ratios were lower under the Food Stamp Program than they were under the Food Distribution Program and vitamin C ratios higher (table 3). In every case comparing food distribution and food stamp participant households, seasonal effects may be operative, and in all cases, for all groups in the sample, differences between the means, where they exist, are small.

It appears the Food Distribution Program was not as effective in improving the nutritional level for participants as compared to

nonparticipants as the Food Stamp Program. Yet, continuing sample households had lower ratios for calories, calcium, iron, vitamin A and riboflavin and a higher ratio for vitamin C when they were under the Food Stamp Program than when they were the Food Distribution Program. Apparently, given their choice among foods, they chose less of the ones they were given under the Food Distribution Program which provided calories, calcium, iron, vitamin A, and riboflavin and more foods containing vitamin C. But their choices differed from those of newcomers to the Food Stamp Program and from the sample as a whole.

The findings of some relatively lower mean ratios for calcium, vitamin A, and vitamin C (table 3) accord with the findings of the 1955 and 1965 United States Department of Agriculture national surveys of household food consumption, the Ten State Nutrition Survey, the Preschool Nutrition Survey, and the preliminary findings of the First Health and Nutrition Examination Survey (Owne, et al.; USDA 1961, 1969, 1965, and 1972; HEW 1974, 1972).

Programs may affect different groups differently, as far as nutrition is concerned, since income, consumption patterns, and dietary patterns of participants, particularly as influenced by ethnicity, have a bearing on how nutrition will be affected (Bischel, Bradfield and Coltrin, Bradfield and Brun, Fleigel). Further research on interactive effects of variables affecting nutritional achievement levels of households appears to be indicated. Making additional food or income in the form of food stamps available to those eligible for food-aid program participation may affect the quantity, quality, and types of food purchased, received, and consumed in some cases (Logan and DeLoach).

According to related studies, means for improvement of nutritional achievement levels for subsets for which some nutrient intakes were below recommended levels may involve education, require further research for their specification, and will probably vary among different segments of the population having different social, cultural, and economic characteristics and living in different areas (Adrian and Daniel; Bischel; Bradfield and Coltrin; Bradfield and Brun; Fleigel; Gifft, Washbon, Harrison; Madden and Yoder; Price, West, Scheier).

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Monthly Steer and Heifer Supply

Glenn Nelson and Thomas Spreen

The manner in which producers form price expectations is often a destabilizing influence on observed prices. Recent price trends are extrapolated, leading to delayed or accelerated marketings which reinforce the existing price trend. An analysis of monthly steer and heifer slaughter yields this conclusion. The theoretical framework links capital theory with the hypothesis concerning extrapolation of price trends. Apparent conflicts in previous studies of the short-term response of slaughter to prices are clarified and partially resolved by the theoretical and empirical results.

Key words: estimating short-term slaughter, price expectations, supply of cattle.

The problem of explaining short-run cattle supply has been addressed by several authors in this *Journal* and elsewhere who have adopted various approaches which will be reviewed shortly. The results of these previous studies have been contradictory, and a controversy still exists about the proper specification of a short-run supply relation for slaughter cattle.

This study focuses on monthly steer and heifer supply and attempts to resolve conflicting results from previous studies. The approach taken here incorporates three notable features. First, marketing and inventory decisions of feedlot operators are placed in the context of capital theory. This approach provides a rationale for accelerated or delayed slaughter of animals as the central role of price expectations is put into proper focus. Second, monthly price expectations of producers are formed by extrapolating trend rather than averaging recent observations. While extrapolation is less commonly used than an averaging process, this pattern of behavior is commonly recognized in discussions of the short-term outlook and it merits greater exploration and use in short-term econometric models. Third, parameters for several months are estimated simultaneously, leading to more precise estimates due to exploitation of correlation between the unknown stochastic elements of monthly supply relationships.

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Previous Studies

Early studies that simply specified slaughter cattle supply as a function of live cattle price and feed price often observed zero or negative elasticities of supply with respect to live cattle prices and zero or positive elasticities of supply with respect to feed price (Reutlinger). These results clearly contradicted conventional economic theory. Reutlinger was among the first authors to recognize a rational explanation for the observed negative short-run price elasticity of supply. The nature of cattle is that they are simultaneously capital goods and consumption goods. That is, as capital goods they possess the potential of converting inputs into a marketable product of a different form (Yver), but, at any time, they may be sold to slaughter as consumption goods. Thus, when a cattle producer is faced with a price increase, his decision may be to sell now or he may decide to retain animals in order to take advantage of expected higher prices. Myers, Havlicek, and Henderson have referred to this second pheonomenon as "reservation demand."

Reutlinger estimated a model in which steer, heifer, and cow slaughter were estimated separately on an annual basis. The expected beef-corn price ratio and initial inventory were specified as explanatory variables. Reutlinger obtained a positive coefficient for the steer equation and negative coefficients for the

heifer and cow equations on the beef-corn price ratio variable. Myers, Havlicek, and Henderson estimated a single cattle supply equation using monthly data in the context of a simultaneous equation model for the hog-beef sector. Their results gave a negative coefficient on current beef price. Tryfos estimated a model for Canada using annual data which specified separate equations for beef supply and inventory of cattle. He observed positive coefficients on cattle price for the inventory equation and then estimated supply as a residual. From his results one could infer an inverse relationship between current slaughter and price. Hayenga and Hacklander estimated a monthly supply-demand model for cattle and hogs. They entered the difference between current price and last month's price as an explanatory variable and observed a positive coefficient on this variable in their cattle supply equation.

Though varied in approach, the results of these studies have not resolved the question of what is the correct formulation of supply for slaughter cattle. Elam summarized previous work well:

> The definitive work on short-run livestock supply response remains an elusive goal. In particular, much work is yet to be done on the relative importance of near-term price expectations in explaining current supply. The principal impediment to such a study has been in the past and will likely be in the future a universally acceptable model of the formation of price expectations. (p. 365)

While this study does not contend to be the "definitive study," a new approach is taken which proves helpful in explaining the contradictory results found in previous studies.

Conceptual Framework

The conceptual framework used is a refinement of that proposed by Reutlinger and later used by Myers, Havlicek, and Henderson, and Tryfos. Whereas Tryfos directly assumed that expected prices influence desired inventories, the following framework starts with more basic assumptions from firm and capital theory.

The derivation of the function describing monthly cattle supply consists of two parts. The first step recognizes that cattle simultaneously may be valued in two ways: as capital goods or as consumption goods. Changes in current and expected prices thus affect capital as well as market value, which leads to a sound economic rationale for accelerated or delayed slaughter of cattle. The second step is formulating an expression for expected prices as a function of observed prices.

The capital value of a beef animal on feed, assuming breeding is not a potential use, is defined to be

$$(1)\quad V(a) = P^{*}W(a')e^{-i(a'-a)} - q\int_{a}^{a'} f(x)e^{-i(x-a)}\,dx,$$

where a is current age, a' is age at slaughter, P^* is expected cattle price at slaughter, $W(a')$ is weight at age a', i is the discount factor, q is the feed price, $f(x)$ is the rate of feed consumption at age x, and variable costs other than feed are ignored. The first term on the right side of (1) is the present value of the animal's worth when sold at age a', and the second term is the present value of the cost of future feed inputs. If the feed price is expected to vary, it should be made a function of time and placed within the integral. This possibility is not considered here due to the short-run nature of the problem. The current market value of the animal on feed at age a, is

$$(2)\quad M(a) = PW(a),$$

where P is the current cattle price.

The foregoing framework, originally developed for describing the annual behavior of cow-calf producers (Jarvis), can be extended to model the actions of feedlot operators in a monthly context. Feedlot operators must consider the opportunity cost of not marketing an animal currently on feed (Nelson and Purcell, and references cited therein). This cost equals the present value of the expected net revenue stream which would result from placing new feeders in the lot. The capital value of a new feeder placed in the feedlot at age b, where b is presumably less than a, is

$$(3)\quad U(b) = P^{**}W(b')e^{-i(b'-b)} - \int_{b}^{b'} q^{**}(x)f(x)e^{-i(x-b)}dx - gW(b),$$

where g is the current feeder price, the feed price is allowed to vary over time, and the definition of other variables is analogous to those in (1).

The decision rules for the feedlot operator are summarized in table 1. The operator holds his cattle in the feedlot so long as their capital

Table 1. Decision Rules for the Feedlot Operator

Condition[a]	Action
$V(a) > M(a)$ and $V(a) > U(b)$	Continue feeding cattle in lot
$M(a) \geq V(a)$ and $U(b) > 0$ } $U(b) > V(a) > M(a)$ }	Sell cattle in lot and buy feeders
$M(a) \geq V(a)$ and $U(b) \leq 0$	Sell cattle in lot and leave lot empty

[a] See equations (1)–(3) and accompanying text for variable definitions.

value exceeds their market value and also exceeds the capital value of feeder cattle. When violation of either of these conditions occurs and he sells his feedlot cattle, he will buy feeders so long as their capital value is positive.

Application of the above theory requires formulation of an expression for expected price which is unobservable. The expected cattle price is assumed to be

$$(4) \qquad P^*_t = P_t + (P_t - P_{t-1}) \sum_{j=1}^{3} \alpha_j Z_{jt},$$

where P_t is observed price in period t, P^*_t is the price expectation for period $t+1$ formed in period t, the α_j are unknown parameters, Z_{1t} equals one if the direction of change from P_{t-1} to P_t differs from the direction of change from P_{t-2} to P_{t-1} and equals zero otherwise, Z_{2t} equals one if price has moved either up or down for exactly two consecutive periods and equals zero otherwise, and Z_{3t} equals one if price has moved either up or down for at least three consecutive periods and equals zero otherwise. The hypothesis underlying (4) is that feedlot operators expect recent trends in price movements to continue; furthermore, the expected continuation will be more pronounced as the duration of the trend lengthens and the magnitude of the recent price change increases. Thus, α_3 is expected to be positive and greater than α_2, α_2 is probably positive but certainly less than α_3, and α_1 is indeterminate. If α_1 is negative, this implies feedlot operators regard price fluctuations of only one month's duration as observations interrupting trends in the opposite direction. The selection of the appropriate number and type of Z variables, i.e., price patterns of different economic significance, is clearly somewhat subjective since few, if any, other studies have taken this approach.

The implications of obtaining price expectations by extrapolation are clearer when this technique is contrasted with the geometric lag structures explored by Tryfos (p. 108, 7f). Geometric lag structures express expected prices as a geometric weighted average of past prices with the larger weights on more recent observations. When prices are trending upwards, price expectations formed in accordance with a geometric lag structure are below current observed prices, i.e., producers regard current prices as high and unsustainable in view of historical experience. Note the contrast with the extrapolation hypothesis in which producers expect the upward trend to continue. Analogous logic applies in the case of a downward trend, and a similar contrast emerges. The extrapolation hypothesis is likely to prove appropriate in some circumstances while other hypotheses will work better in other situations.

A monthly cattle supply equation can now be specified. Focusing upon $V(a)$ and a one-month time horizon, i.e.,

$$(5) \qquad a' - a = 1,$$

then

$$(6) \qquad V(a) \simeq P^*W(a') - qF(1),$$

where $F(1)$ is feed consumption in the coming month. Let

$$(7) \qquad \Delta P = P_t - P_{t-1},$$

and consider the relative magnitudes of $M(a)$ and $V(a)$ while substituting (4) into (6) and dropping the time subscript on Z_{jt} for this discussion:

$$(8) \quad V(a) - M(a) \simeq P^*W(a') - qF(1) - PW(a) \simeq P[W(a') - W(a)] - qF(1) + W(a')\,\Delta P \sum_{j=1}^{3} \alpha_j Z_j.$$

The first term on the right-hand side of (8) represents the additional revenue due to the

steer's gain in weight valued at the current price, the second term is the cost of the feed, and the third term is the gain or loss in revenue due to the expected price change. The third term, and more specifically $\Delta P \sum_{j=1}^{3} \alpha_j Z_j$, is the most volatile factor in the short run and thus the most promising variable for explaining variations in monthly cattle supply relative to inventories of heavy cattle. However, these other variables might also enter a monthly supply function based upon their presence in (8) or their influence on $U(b)$: level of slaughter price, P; feed price, q; interest rate, i; and feeder price, g.

The monthly cattle supply at the industry level is thus assumed to be

$$(9) \quad S = h(I, \Delta P \sum_{j=1}^{3} \alpha_j Z_j P, q, i, g, Y),$$

where S is slaughter, I is the inventory of potentially marketable cattle, ΔP, P, q, i, and g are short-term influences on marketing decisions and are the sectoral counterparts of their earlier definitions at the individual producer's level; and Y is a vector of other influences on slaughter which will be noted later. Any problems associated with aggregation are ignored.

The relationship between price and supply in this study is more complex than that postulated in previous studies. An upward trend in observed prices leads to a rise in expected prices. In turn, the capital value of animals on feed rises as well as their current market value. If the increase in capital value exceeds the increase in current market value, marketings are delayed in a manner completely consistent with the usual assumptions of rational economic behavior. Similarly, a downward trend in prices may cause an acceleration of marketings in the short term. Since expected price enters the supply equation with a negative sign, the expected signs on α_1, α_2, and α_3 are the reverse of those outlined in the discussion of equation (4). Thus, the capital effect is expected to cause the sign of α_3 to be negative and larger in absolute value than α_2 which is also negative. The sign of α_1 remains indeterminate. Furthermore, the coefficient on I will clearly be positive as will be the coefficients of q and i. The sign of the coefficient on the feeder price, g, is negative since this causes $U(b)$ to fall. In the short term, feedlot operators are less inclined to replace current cattle with new feeders and in the longer term may even leave their lots empty.

Parameter Estimation

The estimated parameters are displayed in tables 2 and 3. Commercial steer and heifer slaughter were each used as dependent variables. The explanatory variables drawn from (9) include movements in cattle prices and inventories of cattle on feed. The slaughter and inventory raw data were transformed as explained in the appendix. Months differ considerably in the number of days when cattle slaughterhouses are open. Workdays, defined as the number of weekdays less holidays, was thus included as an explanatory variable. Also, a set of quarterly binary variables was included to account for systematic variation in such factors as weather, availability of pasture, and the precision of the data adjustment procedure.

Estimates of slaughter up to nine months after the date of the cattle on feed inventories were computed. A separate equation is specified for each month, yielding a set of nine equations for each of steers and heifers. The weight classes included in each equation reflect the time interval needed for cattle to reach slaughter weight. Placements of cattle on feed were needed as supplements to inventory variables in the more distant months. Placements were adjusted to the shifting fed-nonfed proportion in slaughter in a manner analogous to that outlined for inventory data in the appendix.

The quarterly inventory and monthly slaughter data are linked as follows: *Cattle on Feed* inventories are reported as of January 1, April 1, July 1, and October 1. Thus, the dependent variable of the supply equation for the first month after the inventory report consists of a sequence of January, April, July, and October slaughter. Similarly, the dependent variable of the supply equation for the second month beyond the inventory report consists of a sequence of February, May, August, and November slaughter. The pattern is extended to the other seven equations with similar reasoning. The first observation on slaughter in each equation is drawn from July, August, and September of 1960. The last observation on slaughter is drawn from April, May, and June of 1976. The first and last observations on the inventory variables are (*a*) July 1, 1960 and April 1, 1976, respectively, for the supply equations for one to three months beyond the inventory report, (*b*) April 1, 1960 and January 1, 1976 for the supply equations for four to six

Table 2. Parameter Estimates for Monthly Commercial Steer Slaughter, July 1960 through June 1976, Thousand Head

		Price Trend $/cwt			Steers on Feed by Wt. Class thousand head					Quarterly Placements thousand head			Quarterly Binaries			
Months Beyond Inventory Report	Constant Term	$Z_1\Delta P$	$Z_2\Delta P$	$Z_3\Delta P$	< 700	500–700	700–900	900–1100	> 1100	1st After Inventory	2nd After Inventory	Workdays	I	II	III	R^2
1	−284	−7.1	20.4	23.5	—	—	—	287*	15	—	—	49*	12	−36	−13	70
	(278)[a]	(7.9)	(10.3)	(19.7)	—	—	—	(32)	(58)	—	—	(14)	(38)	(38)	(37)	
2	452	44.3*	0.5	−10.3	—	—	—	225*	—	—	—	14	96*	272*	194*	70
	(358)	(19.5)	(13.8)	(8.5)	—	—	—	(28)	—	—	—	(16)	(42)	(36)	(43)	
3	−336	12.1	−7.1	−4.6	—	—	160*	181*	—	—	—	39*	70*	176*	42*	84
	(203)	(6.8)	(15.7)	(10.9)	—	—	(20)	(23)	—	—	—	(9)	(29)	(25)	(30)	
4	−331	−14.2*	6.1	−0.5	—	—	159*	127*	—	—	—	50*	42	−62*	−18	79
	(218)	(6.1)	(8.0)	(15.1)	—	—	(22)	(22)	—	—	—	(11)	(33)	(29)	(30)	
5	208	34.7	3.5	−19.3*	—	—	159*	—	—	23*	—	23	99*	265*	208*	74
	(330)	(17.5)	(12.8)	(7.6)	—	—	(23)	—	—	(9)	—	(15)	(49)	(32)	(39)	
6	−151	9.6	−23.8	−21.6	—	123*	113*	—	—	42*	—	36*	41	105*	17	82
	(210)	(7.2)	(16.5)	(11.2)	—	(25)	(22)	—	—	(7)	—	(10)	(39)	(34)	(43)	
7	−193	−8.1	4.4	−11.9	—	94*	122*	—	—	33*	—	46*	19	−73	−76*	79
	(217)	(6.0)	(8.1)	(15.3)	—	(35)	(31)	—	—	(7)	—	(11)	(57)	(51)	(33)	
8	189	31.2	6.7	−19.7*	97*	—	—	—	—	38*	25*	24	101	209*	87*	78
	(306)	(16.4)	(12.1)	(7.1)	(16)	—	—	—	—	(9)	(10)	(14)	(51)	(52)	(39)	
9	−278	6.7	−26.8	−25.5*	120*	—	—	—	—	48*	34*	40*	112*	140*	39	82
	(216)	(7.2)	(16.7)	(11.4)	(14)	—	—	—	—	(8)*	(8)	(10)	(41)	(44)	(29)	

Note: See text for detailed discussion of variables and procedures.

* Indicates parameter estimate is at least twice the estimated standard error, which is a useful rule-of-thumb guide to significance.

[a] The figures in parentheses are the standard errors of the above coefficients; degrees of freedom were adjusted for the number of explanatory variables.

months beyond the inventory report, and (*c*) January 1, 1960 and October 1, 1975 for the supply equations for seven to nine months beyond the inventory report. Hence, the dependent variables for equations (1), (4), and (7) are identical sequences of January, April, July, and October slaughter; the dependent variables for equations (2), (5), and (8) are identical sequences of February, May, August, and November slaughter; and the dependent variables for equations (3), (6), and (9) are identical sequences of March, June, September, and December slaughter. There are sixty-four observations on each equation, i.e., four from each of sixteen years.

Because of the manner in which the equations were constructed, substantial correlations among the random disturbances within the groupings 1, 4, 7; 2, 5, 8; and 3, 6, 9 were expected. Thus, seemingly unrelated regression (SUR) was appropriate, resulting in a marked reduction in the variances of the parameter estimates (Mehta and Swamy). The correlations of the estimated residuals across steer and heifer equations were not large, so each sex was estimated separately.

The presence of cattle prices in the model causes SUR estimates to be statistically inconsistent since cattle slaughter, cattle prices, and the Z_j are jointly determined. The authors feel that the bias in the SUR estimates is not likely to be large because of the large variation in the variables. However, the estimation technique of instrumental variables was utilized to gain consistent estimates. These results were disappointing and are not presented here.[1]

Several regressions were computed prior to obtaining the results reported in tables 2 and 3. An earlier model did not contain price responsiveness (Spreen and Nelson). Feed prices, an interest rate, and feeder prices were included as explanatory variables at one point since the capital theory approach suggests they play a role. However, the relevant parameters varied in sign and were almost never statistically significant. As was anticipated in the discussion

[1] The results can be obtained from the authors. The performance of the instrumental variable equations varied a great deal, with R^2 ranging from 26 to 82. This was not too surprising since the dependent variables were of the form $Z_j\Delta P$, which led to many zero observations interspaced among non-zero observations.

Table 3. Parameter Estimates for Monthly Commercial Heifer Slaughter, July 1960 through June 1976, Thousand Head

		Price Trend $/cwt			Heifers on Feed by Weight Class thousand head			Qtrly. Placements thousand head			Qtrly. Binaries			
Months Beyond Inventory Report	Constant Term	$Z_1\Delta P$	$Z_2\Delta P$	$Z_3\Delta P$	500–700	700–900	>900	1st After Inventory	2nd After Inventory	Work days	I	II	III	R^2
1	−278	4.9	20.0*	−1.5	—	563*	116	—	—	14	−62*	−62*	−321*	89
	(180)[a]	(5.1)	(6.7)	(13.3)	—	(48)	(98)	—	—	(9)	(25)	(26)	(36)	
2	−447*	5.0	3.6	3.5	—	610*	−31	—	—	18	29	94*	−178*	88
	(227)	(11.9)	(8.4)	(5.1)	—	(47)	(83)	—	—	(10)	(25)	(22)	(39)	
3	−341*	14.7*	20.2	12.0	—	641*	30	—	—	8	72*	136*	−87*	92
	(135)	(4.6)	(10.9)	(7.4)	—	(41)	(79)	—	—	(6)	(19)	(17)	(29)	
4	−516	6.1	10.7	−35.8*	184*	179*	—	65*	—	21*	−215*	−121*	−124*	91
	(164)	(5.0)	(5.8)	(10.9)	(45)	(59)	—	(9)	—	(8)	(43)	(31)	(52)	
5	−381	−2.5	8.3	−8.9	160*	—	—	98*	—	13	−275*	8	20	83
	(256)	(13.1)	(9.7)	(5.7)	(33)	—	—	(9)	—	(11)	(37)	(25)	(38)	
6	−471	17.3*	−10.1	−7.6	163*	—	—	103*	—	15	−260*	30	102*	85
	(178)	(6.1)	(14.2)	(9.7)	(32)	—	—	(8)	—	(8)	(36)	(23)	(33)	
7	−263	12.1*	11.9	−45.6*	—	—	—	59*	70*	16	−363*	−383*	−125*	88
	(178)	(4.9)	(6.6)	(12.5)	—	—	—	(11)	(11)	(9)	(34)	(53)	(29)	
8	−401	−2.8	11.7	−10.6	—	—	—	26*	103*	15	−334*	−68	104*	81
	(269)	(13.8)	(10.3)	(6.0)	—	—	—	(9)	(12)	(12)	(39)	(46)	(33)	
9	−448*	18.1*	−11.6	−9.9	—	—	—	22*	108*	16	−319*	−32	193*	82
	(197)	(6.8)	(15.8)	(10.7)	—	—	—	(9)	(11)	(9)	(39)	(45)	(29)	

Note: See text for detailed discussion of variables and procedures.

* Indicates parameter estimate is at least twice the estimated standard error, which is a useful rule-of-thumb guide to significance.

[a] The figures in parentheses are the standard errors of the above coefficients; degrees of freedom were adjusted for the number of explanatory variables.

following equation (8), changes in the more volatile variables dominate short-run decisions. Finally, the exclusion of the weight classes from certain equations was based upon the sign and magnitude of the estimated parameters as well as prior notions of the rate of weight gain.

Model Evaluation

The adequacy of the model underlying the results in tables 2 and 3 was initially examined in terms of how well it described the original sample of observations. First, current price and lagged price were entered separately rather than as the first difference, ΔP. The resulting coefficients were of opposite sign and nearly equal in absolute magnitude, supporting the functional form of ΔP. Second the Z_j alone, rather than $Z_j\Delta P$, were entered. The purpose was to ascertain whether price trend alone affected marketing decisions rather than the interaction of price trend and magnitude of change. This formulation led to lower statistical significance on the Z_j as compared to $Z_j\Delta P$ and lower explanatory power for the equations as a whole. Finally, the unexplained residuals were examined with special attention to 1973 and 1974 when factors associated with price expectations weighed more heavily relative to the rate of gain processes that dominated the earlier period. The earlier model that did not allow for price responsiveness performed very poorly over this period (Spreen and Nelson). In the case of the refined model, no observation appeared inconsistent with the hypothesized structure.

The structural validity of the model was then tested by extending the regression analysis through December 1976 and applying the F test (Chow). While the test is valid in only an asymptotic sense when applied to SUR, the results serve as a useful, approximate indicator of structural validity. The critical F values for rejection of structural validity were roughly 3 and 5 at the 5% and 1% levels of significance, respectively. The results were

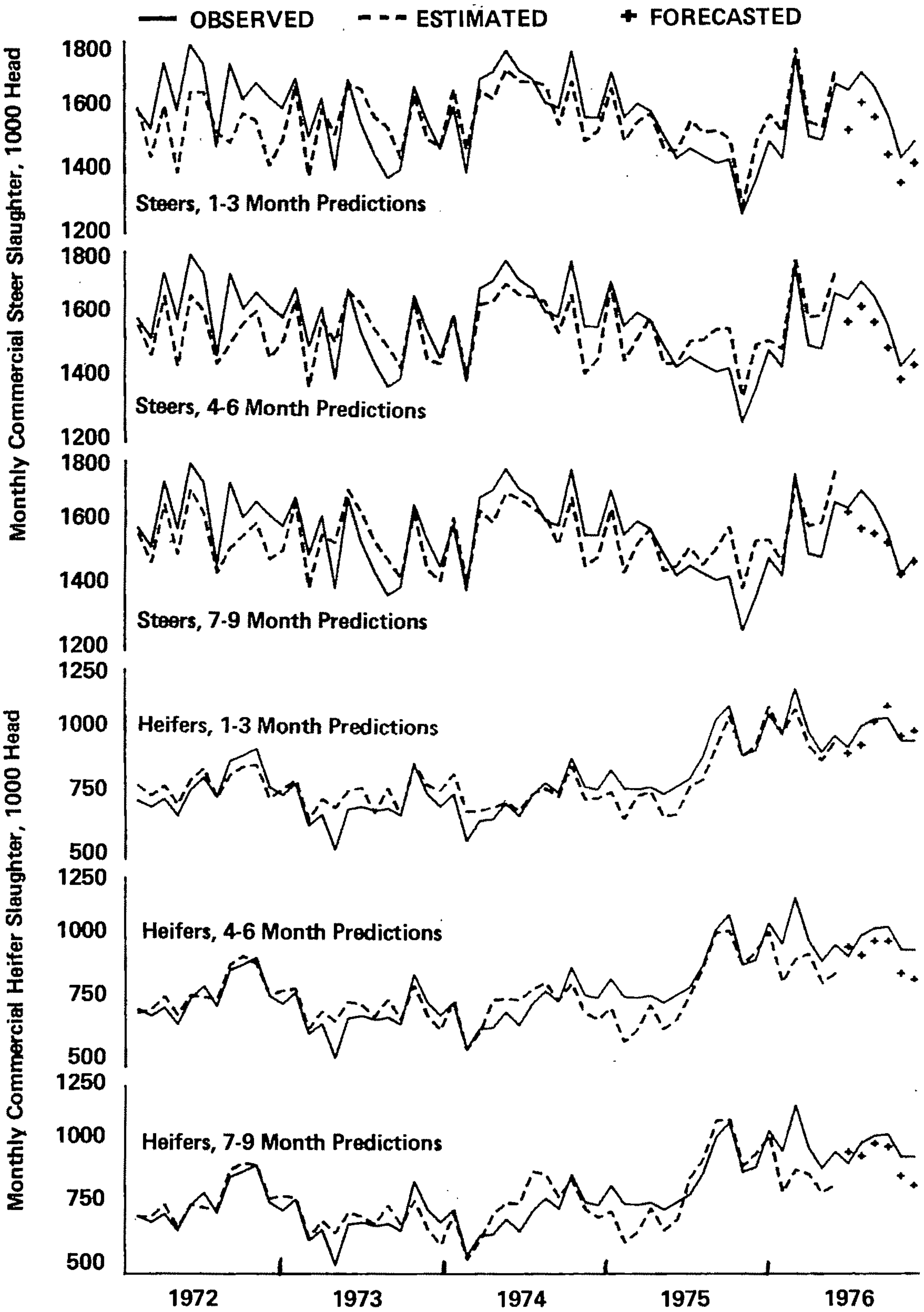

Figure 1. Observed, estimated, and forecasted steer and heifer supply, January 1972 through December 1976

encouraging, because the computed F statistics ranged from .14 to .89 with a median of .53.

Finally, *ex post* forecasts of steer and heifer slaughter were computed for July through December of 1976. Most of the forecast errors are within a range of 3% to 7% of observed slaughter as shown in figure 1. Actual and estimated slaughter for January 1972 through June 1976 are also included in figure 1 to demonstrate how the model performed over this volatile period.

Conclusions

This study reaffirms the usefulness of the *Cattle on Feed* inventory data in estimating short-term steer and heifer slaughter. However, the data need to be transformed properly and relevant variables included to obtain reliable parameter estimates for the inventory variables. Exploiting the correlation between random disturbances in the context of short-term models of this form can lead to a major improvement in the asymptotic efficiency of the parameter estimates. Linking the concepts of cattle as capital items and price expectations as extrapolations of recent trends provides a useful framework for the study of marketing decisions.

The response of producers to current and recent prices is more complex than is recognized in many models. While exceptions are evident in tables 2 and 3, a general tendency is found for slaughter to be directly related to ΔP if the direction of price change in the interval of t-1 to t is different from that of t-2 to t-1 (as shown by the coefficients of $Z_1\Delta P$). Using Fisher's distribution-free sign test (Hollander and Wolfe, pp. 39–45) on the eighteen α_1 coefficients (of which 13 are positive), we find that these results have only a .05 probability of occurring by chance if there is not a direct relationship. However, slaughter tends to be inversely related to ΔP if the most recent price change is a continuation of a trend (as shown by the coefficients of $Z_3\Delta P$). In this case Fisher's sign test applied to the eighteen α_3 coefficients (of which 15 are negative) indicates only a .004 probability of this result occurring by chance if there is not an inverse relationship. The eighteen α_2 coefficients tend to be positive, indicating that a "trend" of only two months' duration does not lead to withholding contrary to the original hypothesis. Thus, there is strong evidence for the existence of accelerated or delayed marketing in response to the pattern of recent prices. However, the magnitude of this effect is still subject to doubt as evidenced by the estimated values for the α coefficients and their standard errors. Hayenga and Hacklander used ΔP without adjustment for recent trends and thus estimated a parameter that was an average of two quite different circumstances; the direct relationship dominated. Tryfos and Myers, Havlicek, and Henderson found the inverse relationship to dominate, although their functional form differs considerably from the one used here. This study indicates a possible resolution of such differences in estimated price response lies in a better specification of the pattern of recent prices.

These results suggest that the manner in which producers form price expectations is often a destabilizing influence on observed prices. A pattern of rising or falling prices for as little as three months leads to an expectation that the price trend will continue and thus to withholding or accelerated marketings, respectively; these marketing decisions accentuate and exaggerate the price pattern, in the manner of a "self-fulfilling prophecy." A one-period price reversal apparently does not change the perception of the underlying trend. A one-month decline after several months of rising prices tends to be associated with decreased marketings; a one-period increase is associated with increased marketings. Both types of behavior tend to cause the previous trend to reappear. Eventually the price trend reverses for three or more periods due to more basic forces of supply and demand. The process may then repeat itself in the opposite direction. While perhaps not important in many periods, taking account of this behavioral pattern is important in volatile periods such as 1973 and 1974. These periods are, of course, precisely those in which good analysis is most valuable to policy makers and private decision makers.

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Appendix

Data Transformations

Estimates of monthly commercial steer and heifer slaughter were obtained by multiplying monthly federally inspected steer and heifer slaughter by the ratio of total monthly commercial cattle slaughter to total monthly federally inspected cattle slaughter. This procedure circumvents the problem of the increasing coverage of the federally inspected series. However, the resulting estimates of commercial steer and heifer slaughter may be too high since cow slaughter may occur disproportionately in plants not subject to federal inspection (Keith and Purcell).

The quarterly *Cattle on Feed* data are the most relevant inventory figures for a monthly study. The feedlot inventory figures were adjusted to account for the varying proportion of steer and heifer slaughter not fed in feedlots. The data transformation for steer inventories was

$$IS^*_{js} = IS_{js}\,(C_s/M_s) \tag{10}$$

where IS^*_{js} is the adjusted inventory figure for steers in weight class j and expected to be marketed in quarter s, IS_{js} is the reported inventory figure for steers in weight class j and expected to be marketed in quarter s, C_s is commercial slaughter of steers and heifers in quarter s, and M_s is fed cattle marketings in quarter s as reported in *Cattle on Feed*. An analogous procedure was used for transforming heifer inventories.

Notes

Effects of Protein and Fat Pricing on Farm Milk Prices for the Five Major U.S. Dairy Breeds

Blair J. Smith and Stephen D. Snyder

The possibility of applying price differentials to the protein or the solids-not-fat portions of milk has been promoted with varying degrees of support for several years. Multiple component pricing may some day become a reality over a large portion of the United States, but how soon this will happen depends a great deal on the attitude of milk producers toward any particular pricing alternative that may be proposed. Lower levels of butterfat are associated with lower levels of both protein and solids-not-fat, so we might expect owners of Holstein herds to be skeptical of payment plans which would include differentials in addition to fat. Owners of Jersey herds, on the other hand, would be expected to look upon such plans with favor. Since Holsteins make up about 90% of the dairy cow population, it is little wonder movement toward some sort of multiple component pricing plan has been slow.

The rationale for switching from the present single component to a dual component pricing system is fully developed in Graf, Jacobsen and Walker, Johnson, Manchester, Snyder and Smith, Webster, and the two-part report by the Ontario Milk Marketing Board. Opinion among these writers is divided on the matter of which other component, protein or solids-not-fat, the second differential should be applied to. Since protein is the only constituent other than butterfat that varies significantly in milk, it is more straightforward to apply differentials to variations in protein rather than to variations in solids-not-fat. Protein is more highly regarded in the human diet than milk sugar, the other major component of solids-not-fat, and is probably more saleable through appropriate advertising and promotion. Furthermore, methods of testing for protein are considered to be more accurate and less expensive than those used for solids-not-fat. An advantage to basing differentials on solids-not-fat rather than protein is that a definite price for nonfat dry milk powder is established in the national market. Although the conversion of skim milk into powder is the use of last resort, variations in the solids-not-fat content of milk are worth at least the price of the additional powder yielded. Since variations in solids-not-fat are due almost entirely to variations in protein levels, then variations in protein are also worth at least what nonfat dry milk powder is worth. Then too, cheese yields depend principally on the protein content of milk, so the value of additional protein is also at least equal to the value of the additional cheese that may be made from it.

The objective of this study was to estimate the potential mean and range of changes in farm prices that would be experienced by herds in each of the five major dairy breeds if any one of nine alternative combinations of fat and protein differentials were to be employed throughout the United States. The alternative payment plans considered were all the possible pairings of protein differentials of 5¢, 7¢, and 9¢ with fat differentials of 6¢, 8¢, and 10¢ per point (0.1%) of variation in protein and fat content, respectively. The nine combinations used were selected to be reflective of the butter and nonfat dry milk powder prices that prevailed during the 1973–74 period.

Previous Related Research

A comprehensive bibliography on the economic aspects of pricing milk components other than butterfat may be found in Snyder and Smith. Hillers and others discuss the effects of seventeen different pricing systems using various combinations of fat, protein, solids-not-fat, and fluid carrier differentials, but generalizations regarding effects on breed groups were limited, and extensions to the national market were not made. LeBaron and Brog showed how changing market values of components could alter the receipts of a small sample of producers in Utah, if payment on the basis of product values was used. Snyder and Smith reported the potential effects of twenty-five combinations of fat and protein differentials on prices to a selected sample of Pennsylvania producers, but breed proportions in their data were not representative of either Pennsylvania or the United States. Some other studies that deal with the potential economic effects

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Table 1. General Characteristics of Study Herds and 1973–74 Base Prices

Breed	No. of Herds	No. of Cows	Cows per Herd	Breed Percentages		Base Prices at Herd Butterfat Test[b]	
				Sample	U.S.[a]	Mean	Range
Ayrshire	12	648	54	8.0	0.8	8.82	8.56 to 9.07
Guernsey	19	988	52	12.2	3.6	9.26	8.92 to 9.54
Holstein	71	4,899	69	60.7	90.5	8.56	8.26 to 8.83
Jersey	19	912	48	11.3	4.1	9.58	9.37 to 9.86
Brown Swiss	15	630	42	7.8	1.0	8.79	8.58 to 8.89
All	136	8,077	59.4	100.0	100.0	8.62[c]	8.26 to 9.86

[a] Estimated for the United States from national DHIA data, assuming all other breeds and unclassified dairy cattle would be proportionately distributed among the five major breeds or would not significantly affect the redistribution of incomes among the major dairy breeds under the alternative payment plans evaluated. Cows were added to each breed group at the mean production values for each breed (table 2) to yield the breed percentages shown for the United States.
[b] Based on Federal Milk Marketing Order No. 4 prices and expressed in dollars per hundredweight. The average butterfat differential in Order No. 4 for the 1973–74 period was 7.8 ¢ per point.
[c] The averages for each breed weighted by the U.S. breed percentages.

of fat and protein, or fat and solids-not-fat payment plans, are those by Blakley, Brog, Luedtke and Stelly, and the Ontario Milk Marketing Board. Although these are of interest, they lack the focus of application and the level of generalization that was sought in the present study.

Data and Procedures

The basic production data for this study were the 1973 and 1974 monthly DHIA test day reports for 136 herds in Pennsylvania under a special research project which included tests for protein content. The general characteristics of these herds are shown in table 1. From the test day data for each cow in each of the sample herds, daily and monthly totals of milk, fat, and protein were developed. The herd yield data that resulted are shown in table 2. These data were supplemented by the addition of cows at the mean breed values for milk, fat, and protein in numbers sufficient to make the breed proportions approximate the U.S. percentages shown in table 1, so that generalizations to the U.S. milk market as a whole could be made.

To permit direct comparisons among the alternative payment plans studied, the total value of the milk sold was always made to equal the value of the milk in the base situation. That is, while individual herds might lose or gain, the sum of the returns to all herds would not change.

A base price for each herd for each month was developed using Middle Atlantic (Federal Milk Marketing Order No. 4) class I and class II prices, utilizations, and fat differentials. These base prices were multiplied by the quantities of milk produced by each herd each month, and the products were summed across herds to obtain a base value of the pool for that month.

The value for each monthly base pool thus established was then redistributed among herds under each of the nine alternative payment plans. In general, a different standard pool price for milk of 3.5% fat and 3.3% protein was computed for each month for each payment plan. This was done by first computing values, in accordance with the differentials

Table 2. Milk, Protein, and Fat Yields for the 136 Herds Included in the Study

Breed	Milk per Cow[a] (pounds)	Percentage Protein		Percentage Fat		Protein to Fat Ratio
		Mean	Range	Mean	Range	
Ayrshire	13,138	3.40	3.27 to 3.52	4.18	3.85 to 4.50	0.813
Guernsey	11,295	3.62	3.43 to 3.82	4.75	4.25 to 5.12	0.762
Holstein	15,186	3.26	3.03 to 3.43	3.83	3.48 to 4.19	0.851
Jersey	9,727	3.93	3.77 to 4.23	5.16	4.73 to 5.65	0.762
Brown Swiss	12,977	3.63	3.19 to 3.88	4.17	3.82 to 4.52	0.871
All[b]	13,757	3.30	3.03 to 4.23	3.90	3.48 to 5.65	0.846

[a] Computed by dividing total milk production for each herd by the number of cows in milk. Since dry cows are excluded, figures are higher than the rolling herd averages reported by DHIA.
[b] Production per cow, protein, and fat percentages for all breeds combined were developed by weighting individual breed averages by the U. S. breed percentages in table 1.

in a particular plan, for the fat and protein that were in excess of the standard levels. These values were then subtracted from the total value of the pool for that month, and the result divided by the total hundredweight in the pool to yield the standard price for the plan of interest. Individual herd prices were then developed by adjusting the standard prices by the value of the deviations in fat and protein from the levels used as standards.

The standards for both components were arbitrarily selected. Any other combination of fat and protein levels could as well have been used, and the same herd prices would have resulted under any particular payment plan. For a detailed description of the procedures actually used to compute the appropriate base, standard, and herd prices, the report by Snyder should be consulted.

Although the alternative prices a herd might receive in any given month could vary negatively or positively from its own base price, only the averages for the 24-month period are presented in this report. The base price averages for each breed are shown in table 1. The deviations from the base prices expected under each alternative payment plan are shown in table 3.

Effects of Payment Plans on Producer Prices

In comparing alternative plans to the base price situation, the following generalizations may be inferred from the data in table 3: (*a*) all Jersey herds would always gain; (*b*) all breed groups except Holstein would always gain (or at least not lose), while the Holstein breed group would always lose (or at least not gain); (*c*) there would always be some herds in every breed group that would gain under every plan; and (*d*) small changes in the prices received by Holsteins would be accompanied by large changes in the prices received by the other breeds since Holsteins make up such a large percentage of the U.S. cow population.

When comparisons among the nine plans studied are made without reference to the base situation, the following generalizations are worthy of note: (*e*) if the protein differential is held constant while the fat differential is increased (plans 7–6, 7–8, an 7–10, for example), or the protein differential increased as the fat differential is held const (plans 5–6, 7–6, and 9–6, for example), Hols lose relative to all other breed groups; and (*f*) sum of the protein and fat differentials is held

Table 3. Differences Between Prices for Selected Protein-Fat Payment Plans and Base Prices [illegible] Breed Groups

Differential (¢ per pt.)		Differences In $/cwt.		% Herds With[a]		Differences In $/cwt.		% Herds With[a]		Differences In $/cwt.		% Herds With[a]	
Protein	Fat	Mean	Range	Gain	Loss	Mean	Range	Gain	Loss	Mean	Range	Gain	Loss
		Ayrshire Herds				Guernsey Herds				Holstein Herds			
5	6	.00	−.05 to .06	58	33	.01	−.11 to .09	58	32	.00	−.10 to .10	23	5[illegible]
5	8	.06	.00 to .11	92	0	.18	.11 to .27	100	0	−.02	−.14 to .05	14	7[illegible]
5	10	.11	.00 to .22	92	0	.35	.24 to .51	100	0	−.03	−.17 to .09	17	72
7	6	.02	−.04 to .09	58	25	.08	−.08 to .17	84	5	−.01	−.15 to .12	20	20
7	8	.08	.00 to .16	92	0	.25	.14 to .36	100	0	−.02	−.19 to .07	15	75
7	10	.13	.00 to .26	92	0	.42	.29 to .60	100	0	−.04	−.23 to .11	14	77
9	6	.04	−.04 to .13	67	25	.14	−.05 to .26	95	5	−.02	−.20 to .13	20	69
9	8	.10	.00 to .20	92	0	.31	.18 to .46	100	0	−.03	−.24 to .08	15	76
9	10	.15	.00 to .30	92	0	.48	.35 to .70	100	0	−.04	−.28 to .13	15	76
		Jersey Herds				Brown Swiss Herds				All Herds			
5	6	.10	.05 to .15	100	0	.12	−.02 to .23	93	7	.00	−.11 to .23	28	50
5	8	.35	.26 to .46	100	0	.17	.01 to .23	93	0	.00	−.14 to .46	22	66
5	10	.60	.47 to .79	100	0	.23	.03 to .31	100	0	.00	−.17 to .79	25	66
7	6	.22	.15 to .31	100	0	.18	−.02 to .33	93	7	.00	−.15 to .33	27	19
7	8	.48	.36 to .63	100	0	.24	.01 to .33	93	0	.00	−.19 to .63	23	68
7	10	.73	.56 to .96	100	0	.29	.03 to .40	100	0	.00	−.23 to .96	22	70
9	6	.35	.25 to .47	100	0	.25	−.02 to .42	93	7	.00	−.20 to .47	27	63
9	8	.61	.45 to .79	100	0	.30	.01 to .42	93	0	.00	−.24 to .79	23	69
9	10	.86	.66 to 1.12	100	0	.36	.03 to .48	100	0	.00	−.28 to 1.12	23	69

[a] Herds must have had potential gains or losses equal to or greater than one cent per cwt. to be included in either column. The other herds, if any, were within 1¢ of the base price. The All Herds figures are the individual breed averages weighted by the U.S. breed percentages in table 1.

stant and increases in the protein differential are offset by equal decreases in the fat differential (as depicted in figure 1), Brown Swiss and Holsteins both experience small relative gains at the expense of the other breeds.

Holstein herds would generally be best off under the 5–6 protein-fat plan and worst off under the 9–10 plan. Of the remaining seven plans, the one least disadvantageous to Holsteins would seem to be the 7–6 plan, where the average loss is 1¢ per hundredweight and the range in differences is −15¢ to 12¢. Under this plan, 20% of the Holstein herds would lose 1¢ or more, 20% would gain 1¢ or more, and the remaining 60% would receive prices within 1¢ of the base price. The 7–6 plan would also be least disruptive over all breeds, for 27% of all herds would gain 1¢ or more and only 19% would lose 1¢ or more. The remaining 54% would face price differences less than 1¢ away from their respective base prices.

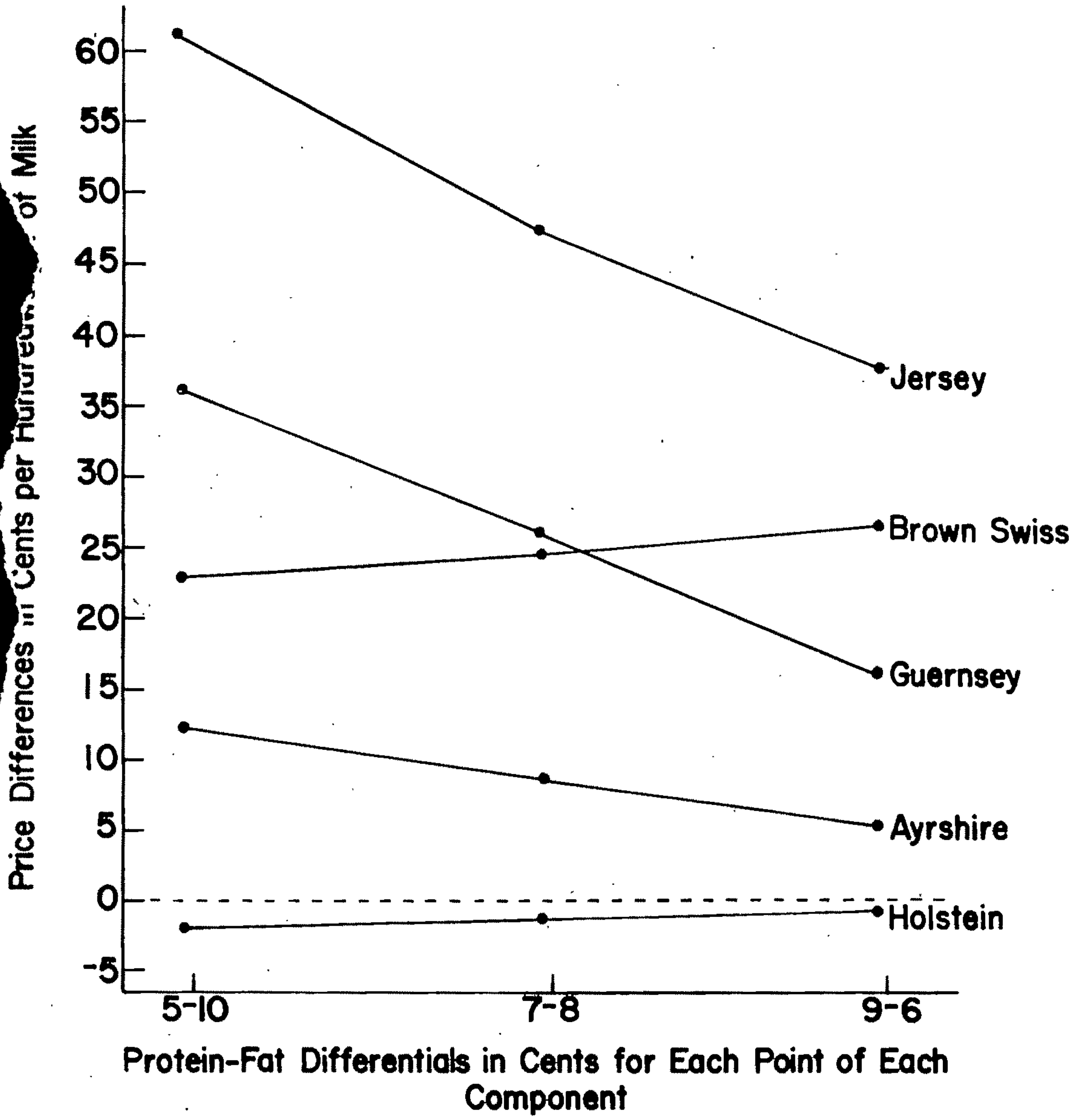

Figure 1. Effects on average prices received by the major breed groups as the protein differential is increased and the fat differential is decreased by offsetting amounts. (Price differences are plotted to the nearest one-tenth of a cent. A point of protein or fat equals one-tenth of one percent.)

mplications and Limitations

'his study suggests that Holstein owners as a group eed not have a great deal of apprehension about he effects that protein differentials might have on he prices they receive for milk. The breed as a /hole would lose at most 4¢ per hundredweight under the 7–10 and 9–10 payment plans), this being nly 0.5% of the 1973–74 base breed blend price of 8.56 (table 1). The greatest loss that would be ustained by any individual Holstein herd would be 8¢, 3.3% of the 1973–74 base blend price of \$8.47 or that herd. At the same time, under the same lan, one Holstein herd would gain as much as 13¢ er hundredweight, 1.5% of the base price of \$8.83 or that herd. For the Holstein breed group for all ine plans combined, the average loss would be .3¢ per hundredweight or 0.3% of the 1973–74 base reed price of \$8.56 already mentioned.

While Holsteins as a breed would absorb small osses under the alternative protein-fat payment lans analyzed, most herds of other breeds would ain, sometimes in rather large amounts. The Jerey breed as a whole, for example, would gain an verage of 48¢ for all nine plans combined. This is .0% of the Jersey breed base price of \$9.58 (table), an average gain greater than the maximum loss o any individual Holstein herd. The most a Jersey erd would gain is \$1.12 per hundredweight on a ase price of \$9.86, or 11.4%.

In the study on which this report is based, the otal value of the money pool that was redistributed mong herds under each of the alternative payment lans was always the same. There is the possibility hat the demand for milk protein can be expanded hrough proper promotion. Certainly the changes in onsumption that are taking place among milk and nilk products suggest a declining demand for nilkfat, and intuitively one feels consumers might espond better to appeals on behalf of protein than hey would regarding milkfat. If this is true, the otal money pool could be expanded to cover the ncreased payments to the high protein breeds vithout disadvantaging the low protein breeds. In ny case, milk with a higher protein level yields nore cheese and more dry milk powder than does nilk with a lower protein level, and it might be ppropriate to reward high protein producers acordingly. Then too, there is evidence that protein roduction can be increased relative to fat producion through feeding, breeding, and selection. What as been lacking is the economic incentive to do so.

The validity of generalizing from 136 herds in Pennsylvania to the effects of alternative protein-fat ayment plans on the entire U.S. dairy industry hould be examined. Are Pennsylvania dairy cows dequately representative of dairy cow populations enerally, and are the particular herds selected rom each breed representative of their respective reed populations? Snyder and Smith assert that he answer to both of these questions is yes, at least so far as the mean values of fat, protein, and milk yield are concerned. Even fairly large biases in the mean values would have little effect on the realignment of prices among breeds under the alternative pricing plans studied. What almost certainly is true, however, is that in expanding limited Pennsylvania data to a national market, the observed ranges in protein, fat, and milk yield measurements are less than those that would be found were all herds in the United States to be included. Hence, the maximum gains and the maximum losses shown in table 3 are probably both less than would be the case if the payment plans studied were in fact to be put into effect on a national basis. The overall breed effects would not be expected to change very much, however, because the mean values for the measures of interest appear to be fairly accurate.

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Insulating Trade Policies, Inventories, and Wheat Price Stability

Thomas Grennes, Paul R. Johnson, and Marie Thursby

Volatile conditions in the world wheat market in the 1970s have revived interest in the subject of wheat price stability. Real wheat prices declined steadily after 1946, and by 1970 prices were as low as at any time in this century except for the trough of the Great Depression in 1932.[1] Prices began to rise in 1971, and they reached their post-war peak in the crop year 1973–74. Since then they have declined, and by the middle of 1977 they hovered near their 1932 level ($1.20 per bushel in terms of 1967 dollars). Several explanations of this episode in the history of wheat prices have been offered, and we have emphasized the importance of government trade policies that attempted to insulate domestic markets from foreign disturbances (Johnson, Grennes, Thursby; see also D. Gale Johnson, Josling). Other interpretations stressed the inadequacy of grain reserves, and recently several world grain reserve plans have been proposed to attenuate future price instability.

The U.S. government proposal calls for a reserve of 25 million tons of wheat, a number which emerges from several other proposals as well. For a discussion of some of the plans see Warley, Trezise, Eaton and Steele, and Sarris, Abbott, Taylor. The level of inventories and the volume of international trade are not unrelated (Johnson and Sumner), and the purpose of this study is to carry out a quantitative investigation of that relationship. Our analytical framework will be a World Wheat Trade Model which we have employed to study related problems (Johnson, Grennes, Thursby), and we will apply it to the circumstances of 1973–74).

Because of the downward pressure on wheat prices since World War II, the major policy problem in the wheat exporting countries before 1972 was how to avoid lower prices and larger inventories. The United States and Canada acquired large inventories as a result of their price support programs, and at times these stocks were larger than a year's wheat production. Two effects of these large-scale government stock operations were (1) to reduce price variability around a declining trend and (2) to reduce the profitability of inventory holding by private firms and other governments. Eventually, the considerable expense of this policy led to an effort to deplete inventories by production controls and export promotion. At a time when the United States was aggressively giving wheat away to some countries and subsidizing commercial exports to other countries, several events, beginning in 1972, brought about a reversal of world market conditions from surplus to shortage. A small world wheat crop in 1972–73 plus a decision by the USSR to respond to a small domestic crop by resorting to imports resulted in the first substantial increase in the real wheat price since 1947. In spite of a record world crop the next year and a substantial reduction in Soviet imports, wheat prices doubled in 1973–74.

Prices were destabilized in the United States in 1973–74 by trade policies in other countries that attempted to insulate domestic markets from conditions in foreign markets. Specifically, in importing countries such as Japan and the European Economic Community, tariffs were lowered, and in exporting countries such as Canada, Australia, and Argentina, foreign sales were discouraged. Notice that insulation does not refer to the level of protection as measured by a tariff or an export tax. It consists of changing the level of protection in response to a change in the foreign price, so as to hold the domestic price constant. Thus, an insulating trade policy involves decreasing the protection received by domestic producers when the world price increases, and increasing protection when the world price decreases. This result is automatically achieved by the EEC variable import levy; and, earlier, the English Corn Laws achieved some automatic insulation by employing both a variable tariff and a variable export bounty (Haberler). Perfect insulation is accomplished when the domestic price is held constant and the effective import demand becomes perfectly inelastic.

The World Wheat Trade Model employed here (Grennes, Johnson, Thursby, chap. 4, and Johnson, Grennes, Thursby) takes both production and inventories as exogenous variables,[2] and it distin-

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[1] For a discussion of the history of U.S. wheat prices in this century, see Grennes, Johnson, and Thursby, chap. 1.

[2] We do not offer a positive theory of the behavior of wheat inventories nor have we seen a satisfactory one. We have also avoided the issue of optimal inventories (see Gustafson, Johnson, and Sumner). Our contribution is the modest one of specifying the implications for trade and prices of alternative exogenous inventory policies.

guishes wheat by country of production. The endogenous countries are the United States, Canada, EEC, Australia, Argentina, and Japan. Thus, the model can show the effect of any exogenous change on all wheat prices in each country and on all trade flows between the countries. To illustrate the mechanics of the model, consider the effects of a 10% increase in U.S. wheat exports to the USSR (an exogenous region). This increase in the demand for U.S. wheat would increase the price of domestic wheat in the United States and in all other countries by the following percentages:

Canada	5.7
Australia	7.0
United States	17.3
Argentina	1.5
EEC	3.5

These figures illustrate the interdependence of national markets and indicate that an attempt by one country to insulate its domestic market from some foreign disturbance would shift the required price adjustment onto other countries.

We can relate trade policy to inventories in terms of their effect on prices. Given an excess demand for wheat, a price increase can be avoided either by an increase in net imports or by a release from inventories. Thus, for each trade policy one can calculate an equivalent inventory release that would have stabilized prices. We can measure the inventory effect of the 1973–74 insulating trade policies by comparing (1) the inventory release which would have stabilized prices in the presence of the actual 1973–74 policies, and (2) the inventory release necessary to stabilize prices in the absence of insulation, which we represent by the actual trade policies of 1972–73.

The effects of these alternative trade policies on the required inventory release are shown in table 1. In the case of constant trade policy, a release of 7.2% from total available supply or 4.197 million tons by the United States would have kept the domestic price at its 1972–73 level. The effect of the actual 1973–74 policies, which shifted demand onto U.S. wheat, was to increase the required inventory release to 12.2% or 7.099 million tons. This increase of nearly 3 million tons measures the extent to which trade policies rendered actual inventories less productive, in terms of stabilizing prices, than they otherwise would have been. Josling (1977) has measured this effect by calculating changes in equivalent producer and consumer subsidies.

Table 1. Inventory Release Necessary to Hold Domestic U.S. Wheat Price Constant

Trade Policy	Percentage	Million Metric Tons
Alternative constant trade policies	7.2	4.197
Actual 1973–74 trade policies	12.2	7.099

Table 2. Inventory Release of All Exporting Countries Necessary to Stabilize Internal Prices

Countries	Percentage	Million Metric Tons
Alternative constant trade policies		
United States	1.0	.415
Canada	1.3	.350
Australia	−9.7	−1.217
Argentina	10.6	.704
EEC	7.0	3.558
Total		3.810
Actual 1973–74 trade policies		
United States	8.7	5.070
Canada	−3.1	−.829
Australia	−26.0	−3.266
Argentina	10.7	.713
EEC	8.8	4.461
Total		6.149

This analysis can be extended to show the effect of coordinating the inventory policies of all the major countries. We can ask what simultaneous inventory changes in the five exporting countries would have been necessary to hold all internal prices constant. The results are presented in table 2. In the constant trade policy case, a total release from inventories by the five countries of 3.810 million tons would have stabilized prices at the previous year's level. This quantity represents approximately 2.5% of the total supply of the exporters in 1973–74. In the case of the actual insulating trade policies pursued in 1973–74, a release from inventories of 6.149 million tons by the major exporters would have been necessary to stabilize prices. This quantity represents about 4% of the exporters' supply in 1973–74, and the difference of more than 2 million tons measures the extent to which insulating trade policies reduced the productivity of existing inventories in terms of price stabilization.

Two relationships should be emphasized in the preceding analysis. First, if some countries pursue insulating trade policies, prices in the remaining relatively open countries will be destabilized. The United States played this role of residual supplier, and we attempted to measure the resulting inventory effect. Second, with regard to stabilizing the U.S. price, this is accomplished more easily by U.S. authorities if all countries are simultaneously pursuing inventory policies that stabilize prices than if the United States is acting alone. In the case

of constant 1972–73 trade policies, it can be seen from tables 1 and 2 that concerted action reduces the required U.S. release from 7.2% to 1.0%. With actual 1973–74 policies the required U.S. release is reduced from 12.2% to 8.7%. These measures of the interdependence of policies show the potential benefits, in terms of inventory saving, of international coordination of trade and inventory policy; and, conversely, they measure the potential costs of ignoring those relationships. This is especially relevant to current discussions of international grain reserves.

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Impact of Alternative Remote Access Computer Systems on Extension Programs

Eddy L. LaDue

A question of concern to extension workers is whether use of computer programs via a remote access delivery system significantly improves extension education programs; and, if so, whether the benefits to extension programs are worth their cost. Relative costs are particularly important in light of the findings of Candler, Boehlje, and Saathoff that extension software must meet higher clarity, speed, and reliability standards than corresponding research software. They contend that while the researcher is normally able and willing to work with the computer and computer programs until useful results are generated, the extension worker wants to use the computer without unrealistic solutions, software malfunction, or hardware breakdown.

This note presents the results of a study designed to assess the cost and value of remote access computer systems in an extension farm management program. Three different delivery technologies—mail-in, touch-tone phone, printing terminal—are compared, and the impact of remote access use on certain characteristics of extension programs is assessed.

The Study

Three groups of extension agent and specialist teams were selected in different parts of New York state. The groups were roughly comparable in background, capability, and geographic representation. Each group consisted of six teams with one to three agents per team. All staff had previously indicated an interest in the use of remote access programs. In addition, teams were selected so that there would be a management agent and dairy agent as part of the team at each terminal location, but resignation and reassignment reduced a few teams to one person.

Each group used a different type of remote access system. For group I, each team used a printing terminal placed at a location convenient for use by extension personnel. Each team in group II was given an Interface System T–16 touch-tone phone pad and a telephone amplifier (touch-tone terminal). Both printing and touch-tone terminals make connection to the computer via normal telephone lines. Responses and results are returned to the terminal in either printed or audio form. The audio responses from the touch-tone terminal are recorded on a precoded output form. Group III used a mail-in system operated by the Department of Agricultural Economics at Cornell University. The mail-in system did not provide computer capacity at field location. Calculations and reports were performed in Ithaca and returned to the field location much like most recordkeeping systems.

Three management decision aid computer programs (Least-Cost Dairy Rations; Capital Investment Model, including Buy versus Custom Hire; and Optimum Machinery Replacement) were made available to all groups for a period of one year. These particular programs use an array of techniques not easily duplicated by hand calculations: linear programming, discounted cash flows, and dynamic programming.

All agents and specialists received training in the use of the specific computer assisted delivery system at their location and in the operation and use of the selected computer programs. Training involved one two-day session, one one-day session, and significant individual consultation. Most of the time spent in training concerned appropriate use of computer programs. Little time was required for training in physical use of the terminals. Emphasis was placed on ways to use programs in educational meetings as well as working with individuals. Detailed users' manuals were developed for each of the three programs (LaDue June 1973, Oct. 1973, and LaDue and Smith Oct. 1973).

For the analyses, farmers were charged a fee designed to cover the long distance phone call and variable computer charges. Agents maintained records of use, cost, and value throughout the trial period. At the end of the one-year period, a questionnaire was completed by each participating team indicating overall reaction to the experience and preference for remote access activity in the future.

Operating Results

During the one-year period, teams using printing and touch-tone terminals ran 253 problems. Aver-

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Table 1. Operating Characteristics and Costs by Terminal Type

Operating Characteristics	Terminal Type: Touch-tone	Printing	Mail-in
Number of problems run	81	172	101
Analyses per problem	3.4[a]	3.4[a]	3.8
	Per Problem		
Phone time (minutes)	27[a]	23[a]	
Phone cost	$ 7.72	$ 6.32	
Computer cost	4.72[a]	4.72[a]	$0.70
Total variable cost	12.44	11.04	
Terminal cost (1974–75)	3.48	20.78	
Terminal cost (sustained use[b])	0.75	10.00	
Total cost (1974–75)	$16.00	$32.00	$4.98[c]
Total cost (sustained use[b])	$13.00	$22.00	$3.50

[a] Standardized to remove differences due to agent team location and number of adjusted analyses.
[b] Assumes a somewhat higher level of use than might be expected with sustained availability of remote access systems.
[c] No postage charge is included. Both the input forms and computer printed results were sent under the franking privilege.

age operating characteristics and costs by terminal type are summarized in table 1. For both the touch-tone and printing terminals, telephone costs per problem increased as the number of adjusted analyses increased. However, as agents developed expertise in system use, average phone time per problem for these two systems dropped from thirty-one minutes per problem during the first six months to twenty-three minutes per problem during the last three months. Printing terminals require at least 15% less time than phone terminals.

Terminal cost for printing terminals is considerably higher than for touch-tone terminals. Even with the somewhat higher levels of use that might be expected with sustained availability of remote access systems, terminal charges could be expected to range from $0.70 to $0.80 for touch-tone terminals and $8.00 to $12.00 for printing terminals at 1976 prices. Further reductions in printing terminal costs can be expected during the next few years, since the price of terminals will likely be influenced by forces similar to those that have caused many prices to decline in the computing industry during the last decade.

During the one-year trial period, average cost per problem for the mail-in system was $4.98 (table 1). Most of the noncomputer operation costs for a mail-in system involve fixed computer costs and personnel. Fixed computer costs include program storage, loading, and maintenance. Personnel costs include clerical time for handling mail and moving problems through the computer, keypunch time to prepare cards for batch entry, and professional time for general management and handling of data submission deficiencies. The corresponding personnel time for the printing and touch-tone terminals is borne by the agent, but it substitutes for hand calculation time required if the computer is not used. Personnel time for a mail-in system can vary significantly depending on the personnel configuration used and the amount of time allocated to mail-in system operation. Since mail to and from the computer during the trial period was sent under the franking privilege, no postage charge is included. First class postage at 1976 rates would increase costs by approximately $0.85 per problem.

Farmers were charged an average of $11.37 per problem run on printing and touch-tone terminals. Farmers did not resist this fee level. Surprisingly, agents sometimes did. At the end of the trial period, agents with printing terminals indicated that a 50% increase in fee (to cover fixed costs) would have little impact on computer use. Touch-tone users believed that such an increase could reduce use by as much as 40%. Since the trial period, some agents have charged significantly higher fees with quite acceptable use levels.

Experience during and since the trial period indicates that the quality and applicability of the computer programs offered are extremely important. Even though the programs offered were carefully selected, more than 85% of the problems run during the trial period were on the least-cost ration program. In general, programs must exactly apply to economically important situations frequently encountered, require only data easily supplied by the farmer, and provide readily usable answers.

Impact on Extension Programs

In evaluating remote access computer systems, an effort was made to determine whether or not computer use had a positive impact on extension programs; and, if so, which delivery system was of most value. Data from the agents' records and the agent questionnaire provided information on both specific characteristics of extension programs and the external image of those programs.

After each individual use of the computer in the field, the extension agent recorded his immediate impression whether the computer program was of

assistance in solving the problem, its impact on agent effectiveness, and the time required to handle the problem. Agents indicated that use of the remote access system provided assistance with the problem approximately 88% of the time. Agents with printing terminals found that the system provided assistance somewhat more often than did those with touch-tone terminals. For about 75% of the problems on which printing or touch-tone terminals were used, agents believed they would have been required to spend more time had the computer capacity not been available. However, the computer sometimes increased the time required to handle a problem, particularly for touch-tone users.

A compilation of agents' impressions indicates that those with access to printing and touch-tone terminals believed their educational effort was made more effective 80% of the time. This response was consistent for both terminals types. Even though more time was required in some cases to solve a problem, there was also greater satisfaction in what was accomplished. In these cases the computer program increased time requirements but also improved the quality of educational effort.

The questionnaire completed by each agent team at the end of the trial period provided an overall assessment of the value of remote access systems. Agent evaluation of the computer programs relative to quality of extension effort is summarized in table 2. Two-thirds of the agents indicated that the program had been improved. None indicated that the quality of the extension program had declined. Half of those who used the mail-in system indicated that their extension program had not been improved. Eighty percent of those with printing terminals indicated an improvement in the overall program.

When asked about the impact of computer assisted programs on specific attributes of extension programs, the array of responses reflected the same basic relationships by type of terminal used that are shown in table 2. Those with printing terminals indicated the most positive impact. Responses from touch-tone users fell in between.

The effect on time required by the agent to solve

Table 2. Effect of Remote Computer Availability on Quality of Overall Extension Programs

Terminal Used	Quality of Program: Improved	Unchanged	Reduced
Printing	80%	20%	0%
Touch-tone	67	33	0
Mail-in	50	50	0
All	67%	33%	0%

problems where the computer was used was mixed (table 3), and there was considerable difference between terminals. Most of those who used printing terminals indicated that time had decreased. All of the agent teams indicating that the time requirement had increased used either a touch-tone or mail-in system. Much of the difference between the printing and touch-tone terminals can be attributed to the need to write down each answer received via the touch-tone units.

Over half the agent teams felt that farmers and agribusiness people held a higher opinion of extension as a result of the use of computer assisted programs in activities in which these people had participated. Only one agent team felt that remote computer availability had diminished extension's standing. That team had used the mail-in system.

About 60% of the users of printing and touch-tone terminals were able to make effective use of computer programs in educational meetings designed to teach management principles while nearly all effectively used programs in one-on-one situations. The printing terminal is particularly limited in its usefulness where a large group (twenty or more) is involved. Even by crowding around the terminal, only a few people can see the result being generated. The touch-tone terminal is better adapted to group use since the results are audible and can be entered by each individual on a copy of the output form.

The main problem with computer use for one-

Table 3. Effect of Remote Computer Availability on Extension Programs, All Remote Access Systems, All Agent Teams

Extension Program Characteristics	Percent of Agent Teams Indicating: Increase or Improvement	No Change	Decrease or Deterioration
Overall quality	67	33	0
Agent time required	22	39	39
Agent ability to handle problems	72	28	0
Farmer evaluation	56	39	5
Agribusiness evaluation	50	50	0
Agent ability to develop instructional materials	56	44	0

on-one and group situations is the lack of availability of the computer at certain times. This may delay agents in handling problems and in some cases may cause the agent to lose the "teachable moment." Lack of availability of the computer is normally the result of the central system being busy or the system being down for repairs or maintenance to hardware or software. University computer systems are particularly unreliable because of continued experimentation with software systems and use of inexperienced operators. The importance attached to reliability by the agents implies a significant advantage of using a commercial time-share system with guaranteed reliability or having the same computer programs available on two or more university computers with access procedures simple enough to provide effective backup. The level of use of computerized decision aids appears to be strongly influenced by the level of certainty that the programs will be available when desired.

All of the agent teams indicated that the computer was a useful tool for self-training of agents and specialists. The speed with which a wide variety of problems can be solved provides a way to evaluate the specific characteristics of particular situations. By using this package to evaluate local situations and conditions, an agent frequently will learn general relationships that hold for his area. In developing these programs, state level extension and research staffs normally spend considerable time on each computer program. A properly tested model provides a more complete and accurate set of relationships than has been available prior to development of the program. Frequently, state staff find inaccuracies and inconsistent relationships in extension materials as they develop a computer program. In the author's opinion, a good computer program can provide one of the highest quality extension packages available.

Terminal System Characteristics

Two characteristics of the touch-tone and printing systems not normally provided by mail-in systems are instant turnaround and results interaction. Seventy percent of the agent groups indicated that instant turnaround, where results come back as soon as the data are entered, was important, very important, or necessary. To focus specifically on the turnaround time required for the mail-in system, agents were asked if mail-in would be adequate for most problems if people were alerted to the turnaround time required. (Turnaround time for the mail-in system operated during the trial period ranged from four to eight days with a mode of six days). Teams were nearly evenly split as to whether mail-in would be adequate. Adding an option where the input could be phoned in and the results phoned back the same day did not significantly improve the acceptability of the mail-in system.

The printing and touch-tone terminals also allow results interaction. In some cases, the initial results contain characteristics that were not anticipated. For example, in ration formulation a result may indicate feeding no corn silage. If a farmer has corn silage, he may want to insist that some minimum level be used—at least to find out how much it would cost to feed corn silage rather than the ration the computer selected. Results interaction involves conducting additional analyses by adjusting the input data in response to the initial results generated. When used in this way, results interaction frequently will provide a more acceptable solution to the problem being considered. Nearly all of the agent teams indicated that results interaction was very important or necessary.

Since results interaction can be conducted most easily with instant turnaround, one might interpret the greater importance ascribed to results interaction as inconsistency. It is likely, however, that the advantage of instant turnaround lies in its ability to facilitate results interaction. That is, farmers frequently would be willing to wait a week or so for a solution, but they want one they can use when they do get it.

This result implies significant limitations for a mail-in remote access system. For many problems an instant answer is not absolutely necessary. However, the limited results interaction possible with a mail-in system would severely restrict effective use of many computer programs by field staff.

Conclusions

Remote access systems can have a positive impact on extension programs. They frequently allow agents to handle problems more effectively and provide a high quality, self-teaching tool. In line with this improvement in extension programs, the external image of program quality is also improved. Costs are now, or soon will be, low enough that farmers will be willing to pay the costs of use of good computer programs.

Results interaction apparently is a necessary feature of a successful computer assisted system. The inability to request alternate solutions immediately after reviewing a set of results implies a significant handicap for mail-in systems. Although currently more expensive than the touch-tone, the printing terminal is superior in performance to both the touch-tone and mail-in. A decrease in printing terminal costs would make this system the appropriate choice for many remote access situations.

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An Assessment of Suffolk County's Farmland Preservation Program

William G. Lesher and Doyle A. Eiler

A primary objective of contemporary land use policy has been to limit or control urban growth. More than forty states have encouraged the preservation of open space, primarily farmland near urban areas, through the enactment of use-value assessment laws which allow farmland to be assessed at its value in use for property tax purposes (Council on Environmental Quality, p. iii). While this type of legislation has not been entirely effective, it does seem to allow a more orderly conversion from agriculture to urban development (Conklin, p. 18).

Because of use-value assessment's inability to limit development, the public purchase of development rights has emerged as an approach to preserving farmland adjacent to urban areas.[1] Such proposals have been introduced in New Jersey, Maryland, Massachusetts, and Connecticut; and a proposal initiated at the local level in New York State has been adopted. Following a four-year planning period, Suffolk County passed a $21 million program to purchase development rights on 3,883 acres of farmland (Lesher, Klein 1976).

Since Suffolk County is pursuing a farmland preservation policy unlike any other unit of government in the nation, it has received considerable attention (Hanrahan, p. 1; Kidder, p. 51). Given that interest, it is appropriate to compare possible impacts of the program.

Land Use in Suffolk County

Suffolk County's 600,000 acres occupy the central and eastern portions of Long Island. It is bounded on the north, east, and south by coastal waters and on the west by heavily urbanized Nassau County. Its western boundary is only forty miles from New York City. Population growth pressures have been high and the suburbs are currently moving across Suffolk County.

There are now, in Suffolk County, approximately 270,000 developed acres (commercial, residential, industrial) and another 60,000 acres permanently committed to recreation or conservation use by public or private ownership (Kunz). Thus, there are still 270,000 undeveloped acres. About 20%, or 55,000 acres, of this is farmland, 41,000 acres of which are harvested cropland (U.S. Dep. Commerce 1976). The remaining 80% is primarily scrub pine acreage.

Most of Suffolk County's population growth is in its western portion, containing over 90% of the county's 1.24 million residents and approximately 62% of its land area. Within this area there are still approximately 80,000 acres of undeveloped land, 5,000 acres of this, farmland (Kunz; U.S. Dep. Commerce 1975).

Eastern Suffolk County is predominantly rural, with 38% of the county's land area and less than 10% of its population. There are approximately 190,000 undeveloped acres, including 50,000 acres of farmland. Most of the farms are on soils well suited for agricultural production. The soils of the nonfarm open space land are predominantly flat and well-drained, suitable for almost any type of nonfarm use, including residential (Scholvinck, p. 5; Raynor).

Agriculture is a major but declining industry in Suffolk County. Over the past two decades, farm acreage has decreased by 50%. One of the reasons for the continuing decline in farm acreage is the nonfarm demand for land. Reflective of this is the $7,500 average per-acre price being paid for farmland that has an estimated agricultural value of $1,500 per acre (Bryant and Conklin, p. 395). About 60% of the farmland is owned by nonfarmers (Gupte, McKay).

For many years Suffolk County farmland has been assessed, de facto, at use-value, which has helped maintain low taxes on farmland relative to taxes on other types of property. Currently property taxes on farmland average $25 per acre. While $25 does not seem unreasonable based upon the land's agricultural value, it is far below the $375 per acre which might result if it were assessed at its full market value (McKay).

An Examination of the Suffolk County Farmland Preservation Program

In 1972 a newly elected county executive became the moving force behind enactment of a farmland preservation program. Following a four-year plan-

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[1] Property rights that flow from fee simple ownership can be viewed as a continuum; that is, land ownership involves a bundle of rights to use the land for several purposes. One such right of farmland ownership is the right to develop the land to a more intense use, commonly called the "development right."

ning period which included committee reports, court cases, and partisan activities, the Suffolk County farmland preservation program became a reality. Even though the initial 3,883 acres are fewer than had been envisioned, the county executive is planning to expand the program gradually through 1979 to 15,000 acres, at a cost of approximately $90 million for the development rights, plus substantial legal and administrative costs.

The primary motivation for passage of the program was to "limit growth." This was most frequently articulated in terms of three broad objectives of the program: (*a*) preservation of a viable agricultural economy, (*b*) maintenance of an aesthetically pleasing rural environment, and (*c*) local tax savings. Using the anticipated total program acreage, total cost estimates, and the locally projected population growth rate of 22,500 per year, we will examine the program's likely accomplishments relative to these objectives.

Preservation of a Viable Agricultural Economy

Suffolk County is the leading agricultural county in New York, with annual gross agricultural receipts of $70 million. Of the 41,000 cropland acres harvested in 1974, 34,000 were devoted to the relatively land-extensive enterprises of potatoes, vegetables, and sod. These enterprises generated approximately $35 million, or 50% of the county's gross farm receipts. On the other hand, the relatively land-intensive enterprises of ducks, flowers/bedding plants, and nursery stock generated $34 million in gross farm receipts on only 6,000 acres of cropland. On a per acre basis, flowers and ducks generate approximately eleven to fifteen times the $1,000 per acre gross receipts of potatoes or vegetables.

While the land-intensive enterprises play an important role in the county's agricultural economy, the farmland preservation program has focused almost exclusively on land currently producing potatoes. If preserving a viable agricultural economy is one of the program's objectives, why have not the 6,000 acres now used in the land-intensive enterprises of ducks, flowers/bedding plants, and nursery stock and generating $34 million in gross farm receipts per year been included?

Economic viability is closely related to the cost of land resources. Proponents have argued that the program will increase the economic viability of agriculture because the purchase of development rights will reduce the price of farmland. But would farmers be financially better off even if the market price of farmland, stripped of its development rights, approximates its currently appraised agricultural value of $1,500 per acre? Certainly those farmers who sold their development rights would realize a substantial capital gain from their land, but this says little about the program's impact on the cost of using the land for agricultural production.

The cost of using the land depends upon whether it is rented or owned. If the land is rented, the per-acre cash rent indicates the farmer's cost in the production process; but if owned, the land cost includes the opportunity cost of the resources invested in the land and the real estate taxes.

Currently 60% of the farmland is owned by "speculators" (Gupte, McKay) who rent to farmers at an average cost of $50 per acre (McKay, White, Newton). If farmers were to buy this land at its agricultural value of $1,500 per acre, their per-acre land cost would be $145 (assuming an opportunity cost of capital of 8% and real estate taxes of $25 per acre). Since speculators are willing to let farmers use their land at a nominal cost, it appears the program will not reduce the farmer's cost of production. One might question whether land costs based solely on the farming rights would be drastically reduced by the program for two reasons: (*a*) competition for additional acreage by farmers who sold their development rights; and (*b*) urban demand. If, in fact, the market price of the preserved acreage would escalate over time, this also would increase the cost of agricultural production because land ownership costs would also increase. Thus, it seems that farmers may have nothing to gain economically from ownership of the preserved acreage with the possible exception of appreciation in value of the farming rights over time.

Furthermore, will land devoid of development rights continue to be used in commercial agriculture? The program does not prohibit the extensive remodeling of old farm houses, the building of white fences, or the raising of black cattle and horses. It also appears that as long as the land continues to be used in "agriculture," this preserved acreage can be subdivided.

Maintenance of an Aesthetically Pleasing Rural Environment

The two aesthetic attributes most often identified with a rural area are an open landscape and a low population density. Thus, we must address the question of whether or not the public purchase of development rights on 15,000 acres of farmland is likely to contribute in any measurable way to the preservation of these pleasing rural characteristics.

The farmland included in the program will be located in eastern Suffolk County, within an hour or two drive for many county residents. While the public will not have access to the land, they will be able to experience the scenic and nostalgic benefits of driving through the area. This may be especially important because eastern Suffolk County is the only rural area conveniently accessible. In addition to the benefits associated with viewing the rural landscape, other residents may derive a vicarious satisfaction just knowing such an area exists. This is often referred to by environmentalists as option demand (Cicchetti and Freeman).

However, the land extensive agricultural enterprises which are most visually enjoyable may not be

economically feasible in the long run. Since the program does not restrict the choice of enterprises, farmers will grow those crops that are most profitable. This may mean a continuum of roadside stands and u-pick operations rather than vast fields of potatoes. Further, the possible conversion of the preserved acreage into country estates may result in a landscape which is no more aesthetically pleasing than large-lot, rural residential development.

Many Suffolk County residents seem concerned about the congestion and pollution frequently accompanying concentrated suburban development. They view the result of the quarter-acre lot subdivisions found in neighboring Nassau County with disdain (Kunz). However, the high-density residential development found in Nassau is unlikely to occur in Suffolk, even without the preservation program, because most of the developable land, including farmland, is zoned for single-family dwellings on lots of at least one acre. Although large-lot zoning may not preserve an open landscape, it will reduce the congestion and pollution problems associated with more dense developments. While local zoning can be altered to accommodate more development, the reverse may also be true. For example, the town of Brookhaven is considered the transition area separating the residential and rural portions of the county (Scholvinck). Recently, the minimum lot size was increased from one to two acres on a sizable tract of land within the town.

Since the farmland preservation program is unlikely to affect the density of residential development, and its ability to maintain a desirable open and aesthetically pleasing landscape can be questioned, will it help restrict population growth? Currently Suffolk County has approximately 270,000 acres of developable land. This includes all of the agricultural land. If the program preserves 15,000 acres of farmland, this means there are still 255,000 acres that can be developed. Assuming four persons per house, one acre lots, and .75 housing units per acre, 255,000 acres would provide housing for 765,000 people. At the current rate of population growth it would be approximately thirty-four years before the preserved farmland would limit the population of Suffolk County.

Local Tax Savings

One of the more generally accepted rationales for limiting urban sprawl concerns tax savings through the reduction in the provision of public services (Council on Environmental Quality). The largest single public service that a local government provides is education. According to a Suffolk County Planning Board Report (Klein 1973, appendix), 100 acres of developed land in Suffolk County in acre lots would have 105 students. The local cost of educating these students was estimated to be $105,000 per year, while the school tax revenue estimated for 100 acres of new residential development was $67,340—a difference of $37,660 per year.

But for these savings to be valid and attributable to the program, one acre of farmland preserved must mean one acre not developed. And this is only true when all the other land is developed so that the preserved acreage actually restricts growth. Any savings accruing from the preservation of farmland must be discounted to its present value. Assuming a 5% interest rate, the present value of a $37,660 perpetual stream of income thirty-four years in the future is $143,485. Thus, the educational cost savings from not developing 100 acres of farmland has a present value of $143,485. The cost of the development rights for 100 acres of land is $600,000.

While over one-half of the local property taxes are for education (Klein, appendix), other public service costs for roads, water, and sewage could also be reduced if the land remained in agriculture. However, even if the actual dollar amount of cost savings from all public services were three times the amount projected for education alone, the present value of these savings would be less than three-fourths the current cost of the development rights.

Furthermore, the cost of the program will be borne by all residents of the county irrespective of where they live, while the cost savings will be realized by the local school and town taxing districts contained within the preserved acreage.

Program Size and Population Growth

Up to this point, the analysis has assumed a farmland preservation program eventually encompassing 15,000 acres. The program currently includes only 3,883 acres, and local residents do not appear anxious to burden themselves with the additional $69 million debt needed to expand the program (Kidder, p. 52). The current program acreage, however, may be below the critical mass needed for agricultural survival (Dhillon and Derr).

New York has the nation's highest per capita state and local taxes (McKeating, Commerce Clearing House) and a less than bright economic outlook. This has led to a flight of business, industry, and people from the state (Weinstein and Keller). Stagnation has already appeared in other urban fringe counties of New York City (Tyran). Thus, the current population growth rate of 22,500 per year in Suffolk County may not continue. If population growth does not continue at its present rate, agriculture will remain on the productive farmland of Suffolk County, even without a farmland preservation program.

Summary and Conclusions

In 1976 Suffolk County initiated a farmland preservation program to manage residential growth through the public purchase of development rights on prime agricultural land. As currently envisioned, the program will acquire development rights on only about one-fourth of the agricultural land in the county. The most likely acreage for

which development rights will be purchased is devoted now to land-extensive crops. On a per acre basis, these crops contribute little to gross farm receipts when compared to the more land-intensive enterprises. It also is possible that the program will increase, rather than decrease, the cost of agricultural production on the program acreage. Furthermore, it may encourage the development of small country estates on the land that is now in commercial agriculture.

The two aesthetic attributes most often identified with a rural area are an open landscape and a low population density. While the program may help to continue an open landscape in limited areas of eastern Suffolk County, it is unlikely that even without the program all of the agricultural land will be developed. In addition, with so little of the potentially developable land included in the program, it appears the purchase of development rights will have little effect on the county's population density. This would appear to be especially significant if the present large-lot zoning is maintained. Thus, it appears the primary aesthetic benefits of the program are limited to the visual and vicarious enjoyment of a rural landscape.

The program will result in cost savings in public services, but on a per acre basis the development rights will cost more than the present value of the most optimistic estimates of public service cost savings. Moreover, any tax savings experienced will benefit those taxpayers who live in close proximity to the preserved acreage at the expense of those who live in western Suffolk County.

While it seems the program cannot be justified on an economic basis, the unique island geography limiting accessibility of alternative open space, the continuing concern about overpopulation, and the relative affluence of the residents may help explain local support for the program.

Considering the uniqueness of the Suffolk County situation and its relatively long struggle to implement a purchase-of-development rights program of modest size, one might very well question whether such a policy instrument will be useful to other areas worried about controlling urban fringe growth.

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U.S. Agricultural Production Capacity: Comment

Pierre Crosson

"Long-range U.S. farm production capacity is unlikely to be challenged by 1985." This is the principal conclusion of a recent article in this *Journal* by Yeh, Tweeten, and Quance (YTQ 1977, p. 47).[1] It is a comforting idea, but analysis of the argument and results on which it is based suggest that it is quite misleading.

The YTQ Argument

The conclusion follows from the finding by YTQ that in 1985 the "feasible supply capacity" (their expression) of U.S. agriculture would be 67% greater than equilibrium demand and output, given a set of projected conditions (p. 47). This margin of excess capacity occurs, however, at real prices (prices received by farmers divided by prices paid) 80% above the 1967 level and 79% above equilibrium level in 1985 (table 2, p. 43). Do YTQ mean that capacity would not be "challenged" until output had risen to 190 (1967 = 100) and real prices to 180 (1967 = 100)? If so, their conclusion is correct, given their measure of capacity; but American consumers and many foreign buyers of American farm products, faced with unprecedently high real prices, likely could find little comfort in it. If YTQ mean that the challenge to capacity would arise only as output approached 190, the consequences for consumers of U.S. farm products are not fundamentally changed because the elasticity of the long-run supply curve (table 2, p. 43) is such that real prices rise more or less proportionately throughout its length as output increases. Suppose, for example, that the shift in the demand curve from 1974 to 1985 were greater than YTQ have projected it, bringing equilibrium demand and supply in 1985 to 131.5, and the real equilibrium price to 120 (table 2). By YTQ's criterion, capacity would not be challenged. However, the real price would be 13% above the 1974 level of 106 (table 2, footnote a); that is, the trend of real prices would be rising, a reversal of the historical trend of real farm prices in the United States. Apart from periods of war and their aftermath and prolonged economic depression, the secular movement of these prices until 1973 was downward, particularly from the end of World War II until the early 1970s, when technological progress in American agriculture was rapid.[2]

I suggest that most consumers, agricultural economists, and those responsible for agricultural policy would regard a long-term rise in the real cost of farm products, reversing the trend of several previous decades, as a highly negative development, even though, by YTQ's definition, capacity were "unchallenged." The argument that capacity were unchallenged likely would be viewed as irrelevant, if not harmful, for it would obscure the emergence of a fundamental and unfavorable change in the cost conditions of American agriculture.

I am not taking issue here with the concept of capacity employed by YTQ. They argue, quite rightly in my judgment, that because it is possible to increase U.S. agricultural production virtually without limit if one is prepared to pay the cost, a concept of capacity as an absolute maximum output makes little sense. Accordingly, they define feasible supply capacity in terms of the elasticity of supply, an approach with which I agree. However, the supply curve they specify for 1985 (table 2) has about the same elasticity at levels of output and prices near equilibrium as at the levels corresponding to feasible supply capacity. Unless the supply curve becomes much less elastic just beyond feasible supply capacity—and there is nothing in the YTQ article to suggest this—then their results show that efforts to increase output much beyond equilibrium would have the same proportionate effect on prices as efforts to increase output at feasible supply capacity. Consequently, the "challenge" to capacity, measured by the behavior of prices, would emerge at levels of output substantially less than the feasible supply capacity specified by YTQ.

The implication of this argument is that YTQ, in accordance with their own definition, should have specified a much lower level of output and prices as corresponding to feasible supply capacity. This might be granted. YTQ still could assert, however, that demand would not challenge capacity by 1985, at least in three of the five scenarios they consider, because equilibrium prices that year in those three scenarios are below the 1974 price (table 2). The margin of unutilized capacity would be much smaller than YTQ assert, but by the criterion of the effect on prices of efforts to increase output, capacity would not be challenged between 1974 and 1985.

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[1] Unless otherwise identified, all page references are to the YTQ article.

[2] U.S. Department of Commerce, pp. 488–489, and USDA (1976).

Analysis of the Argument

This is what the YTQ results show for the three scenarios. However, I find the results difficult to understand. Assuming for the moment that supply, demand, and prices were in equilibrium in 1974, equilibrium prices in 1985 would be lower than in 1974 if the supply curve shifted to the right more than the demand curve. In this case, however, the increase in amount demanded from one equilibrium to the other would be greater than the shift in the demand curve. This does not happen in the YTQ results. On the contrary, in each of the three scenarios the demand curve shifts 17.8% (1.5% annually from 1974 to 1985, p. 42) but the amount demanded at equilibrium prices grows 5.6% in the baseline scenario, 5.8% in the high technology scenario, and declines 1.0% in the high inflation scenario.

The failure of equilibrium demand to grow as much as the shift in the demand curve in the three scenarios is consistent with a shift in the supply curve less than the shift in the demand curve. But, in that case, real prices would be higher, not lower as the YTQ results show.

YTQ say that one of the reasons for the decline in real prices in the three scenarios is that demand is less elastic than supply, both short term and long term, and that this offsets the effect on prices of the greater shift in the demand than in the supply curve. I think this is incorrect. I cannot construct a set of demand and supply curves with the elasticities and shifts specified by YTQ that yield a decline in real prices. Under the specified conditions, real prices ought to rise.

I have assumed so far that demand, supply, and prices in 1974 were in equilibrium. However, if both prices and supply in 1974 were above equilibrium levels, then the results in table 2 would make sense, with supply a function of real prices. That is to say, under the assumed conditions, an increase in the amount actually demanded less than the shift in the demand curve would be consistent with both a fall in real prices and a smaller shift in the supply than in the demand curve.

It strains credulity, however, to believe that price and output were above equilibrium levels in 1974. Prices probably were. Real prices, as defined by YTQ, increased 17% between 1972 and 1974, in large part because of a 40% increase in the quantity of exports. Output, however, declined almost 2%, primarily because of the effects of bad weather on crops (USDA 1976, pp. 442, 455, and 569 for production, prices, and exports respectively). It almost surely is the case, therefore, that in 1974 real prices were above and output below equilibrium. In this event, movement of supply, demand, and prices to equilibrium from 1974 to 1985 would involve a decline in real prices, as YTQ show, but an increase in the amount actually demanded greater than the shift in the demand curve—the reverse of the YTQ results.

The fact is that the behavior of the supply curve in the YTQ analysis is not clear, primarily, I believe, because the effects on supply of inflation in prices paid by farmers are not clear. In four of the five scenarios these prices are assumed to increase 4% annually. In the other (high inflation) scenario they are assumed to grow 8% annually. YTQ assert that inflation in these prices shifts the supply curve to the left at a rate equal to the product of the inflation rate and the elasticity of supply, said to be 1.0 in the long run (pp. 40 and 41). The other supply shifter is total productivity growth, assumed to move the supply curve to the right at the rate of 1.14% annually in three of the scenarios, 1.21% in the high technology scenario and 0.0% in the low technology scenario.

If these words mean what they say, then over the period 1974 to 1985 the supply curve ought to shift to the left in all of the scenarios. Yet it apparently does not, except possibly in the low technology case. Nonetheless, inflation in prices paid by farmers appears to have a negative impact on supply by offsetting some of the effect of productivity growth in shifting the curve to the right. Thus the assumptions about inflation and the mechanics of the process by which inflation impacts on supply seem to be crucial to the results of the analysis. Some discussion of the process would have been useful in evaluating the results.[3]

Some Implications of the YTQ Argument

The behavior of equilibrium prices, demand, and supply from 1974 to 1985 are anomalous in the YTQ analysis if supply is a function of real prices, as YTQ define them. Consequently, I am uncertain whether the movement from 1974 levels of prices, demand, and supply to the equilibrium levels shown in table 2 for 1985 would exert much or little pressure on farm production capacity. The behavior of real prices indicates that it would not. The behavior of real output in response to the shift in demand, however, suggests heavy pressure on capacity. As noted above, equilibrium demand and supply in 1985 would be only 5.6% above the 1974 levels in the baseline scenario, 5.8% above in the high technology scenario and 1.0% below those levels in the high inflation scenario, even though the demand curve would shift to the right by 17.8% in all three scenarios. Equilibrium demand and output would grow much less than the shift in the demand curve in the other two scenarios as well.

These percentages indicate that the ability of American farmers to accommodate rising demand would be substantially weaker in the eleven years

[3] In YTQ, the authors refer to other articles by Yeh and by Tweeten for explication of the effects on supply of inflation in prices paid. However, given the apparent importance of inflation to the results in this analysis, some discussion of that role would have been useful in the article here under consideration.

ending in 1985 than it was in the 1960s and early 1970s. I estimate that from 1959–61 to 1970–72 the demand curve for American farm output shifted to the right at the average rate of 2.17% per year, a total shift of 26.6%.[4] Production in this period increased by 18.4% (69.1% of the shift in demand). Nominal prices received by farmers rose by 21.3% but real prices fell by 10.0% (USDA 1976, p. 455), more than in any of the five scenarios projected by YTQ except the high inflation scenario. Despite the relatively unfavorable behavior of real prices received, U.S. farmers in the eleven years ending in 1970–72 were able to accommodate a substantially higher proportion of the shift in demand than they will be able to accommodate in the eleven years ending in 1985, judging from the results presented by YTQ.

The comparison with earlier performance is particularly striking if one considers the low technology scenario presented by YTQ. In this scenario equilibrium production in 1985 is only 3.1% above production in 1974, 17.4% of the projected shift in demand, and real prices rise by 5.7% (table 2, p. 43). The low technology scenario assumes no increase in total productivity, clearly a pessimistic assumption. However, there is evidence that the projected increases in total productivity in the other scenarios (1.14% annually, except 1.21% in the high technology scenario) are optimistic. Compared with earlier performance, the growth in total productivity and yields slowed markedly in recent years, as table 1 shows. While bad weather and high fertilizer prices may account for some of the slowdown in the growth of yields and total productivity since the early 1970s, it is likely that the experience also reflects the using up of the productivity potential of the technologies on which U.S. farmers have relied since the end of World War II. This argument receives powerful support from a study by the National Academy of Sciences (1975). If the argument is valid and the growth of yields and total productivity diminishes further, the ability of U.S. farmers to respond to prospective increases in demand would be even weaker than the YTQ results show (except for the low technology scenario).

The YTQ projections of equilibrium demand do not separate export from domestic demand. The export component of the demand shifter is assumed to grow at 3.5% annually in the baseline scenario. If actual exports in fact were to grow at this rate, total growth of exports over the eleven years 1974–85 would be 46.0%. If we give exports 14.0% of the weight in total demand growth (the weight assigned by YTQ), then 46.0% growth in exports combined with the projected growth of total demand of 5.6% would imply a decline of 2.3% in domestic demand in the baseline scenario. Since population in the baseline scenario is assumed to increase by 7.7%, per capita domestic demand would decline by almost 10.0%.

[4] The demand curve shifters in the YTQ analysis are population, real per capita disposable income, and exports. I used these factors in estimating the shift in the demand curve from 1959–61 to 1970–72, assuming the income elasticity of demand to be .14 and giving export growth a weight of 14%, the same values used by YTQ. Per capita disposable income and population are from U.S. Government 1977. Agricultural exports are from U.S. Department of Agriculture 1976.

Table 1. Average Annual Rates of Increase in Crop Yields and Total Productivity, United States (percentage)

	1950–52 to 1960–62	1960–62 to 1970–72	1970–72 to 1975–76
Yield index, all crops	2.7	1.8	0.1
Total productivity index	2.4	1.4	1.0

Source: U.S. Government, 1977.

A secular decline in per capita demand of this magnitude would be unprecedented in U.S. history for which data are available, and would have obvious unfavorable impacts on the welfare of U.S. consumers. However, it is unlikely that domestic demand would fall this much, because the growth of export demand would probably be constrained by the increase in nominal prices, although the YTQ article does not indicate by how much. (Page 44 and table 2 for nominal prices in 1974 and 1985, respectively. In the YTQ analysis, demand is a function of nominal prices.) If we assume, for illustrative purposes, that because of higher prices actual exports grow at 2.0% annually instead of 3.5%, then exports would increase by 24.0% from 1974 to 1985, well below the growth experienced in the 1950s and 1960s (USDA 1962, 1976). Again assigning this increase a weight of 14.0%, the implied increase in domestic demand in the baseline situation would be 2.6%, and per capita domestic demand would decline by 5.0%. To avoid a decline in per capita domestic demand, exports would have to fall by about 7.0% between 1974 and 1985.

The baseline (and other) scenarios analyzed by YTQ clearly imply an equilibrium situation in 1985, marked by either a decline in domestic per capita demand for U.S. farm products or a serious erosion of the U.S. position in world agricultural markets, or both. To say that in this situation U.S. farm production capacity would not be seriously challenged obscures the existence of potentially serious problems.

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Possible Implications of Voids in USDA Cattle Slaughter Data: Comment

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In a recent article in this *Journal*, Keith and Purcell expressed the need for collecting and reporting data on number of cows slaughtered in nonfederally inspected plants. Such a data series is required if sound economic research is to be conducted on several important problems of the beef industry.

They conducted three analyses, two arithmetic and one statistical, to demonstrate the likely magnitude of error involved in assuming that nonfederally inspected slaughter consists of the same percentage of cows as is reported for federally inspected slaughter. Our estimates, using the same methods, differ substantially from theirs, causing us to challenge their conclusion that "cow slaughter as a percentage of total slaughter is substantially larger in nonfederally inspected plants" (Keith and Purcell, p. 568). Our estimates also vary widely, which both supports their plea for hard data and makes any single estimate inconclusive.

In both of the arithmetic methods, the authors assume that all heifers intended for replacement actually enter the cow herd. Evidence suggests that only 70% to 85% of heifers bred to calve at two years of age actually conceive (Rogers; Bentley, Waters, Shumway). A replacement heifer does not enter the cow herd until she has had a calf. Therefore, it is highly unlikely that more than 80% to 90% of heifers intended for replacement ever enter the cow herd. With only this one change in underlying assumptions, our calculations using their first method (equation (1) p. 569) yields an estimated cow slaughter for the nine-year period, January 1965 to January 1974, of between 57.818 and 67.226 million head (rather than 76.634 million). These revised estimates imply that cows accounted for only 13.0% to 34.7% of nonfederally inspected slaughter (instead of 56.4%). A 10.0% decrease in heifers entering the herd translates into a 21.7% decrease of cows in nonfederally inspected slaughter.

Their second method (equations (2) and (3) p. 569) estimates the percentage of cows in nonfederally inspected slaughter for the earlier period, 1950 through 1964. It relies on average replacement rates required to maintain a constant herd size. Replacement rates were estimated from number of heifers intended for replacement during 1965–73. If less than 100% of heifers intended for replacement actually entered the cow herd, they overestimated the percentage in nonfederally inspected slaughter for that earlier period also. With 80% to 90% of intended replacements entering the herd, we estimate the annual replacement rate for beef cattle to be between 0.129 and 0.145 per year and for dairy cattle, between 0.235 and 0.264. Table 1 displays the results of the slaughter estimates for these limits. With total commercial cow slaughter estimated between 98.94 and 119.32 million head, a range of 28.7% to 52.3% can be placed on cows as a percentage of nonfederally inspected slaughter in the period 1950–64. Although these estimates overlap slightly with the revised estimates for method 1, they are generally higher.

Cows as a percentage of *federally* inspected cattle slaughter were 27.6% for the period 1950–64 and 24.6% for 1965–73. Therefore, our estimates for the nonfederally inspected category bracket the federally inspected category for the period 1965–73 and approximate it on the lower end for the earlier period. Keith and Purcell's estimates, although representing a narrower range from 40.5% to 64.0%, all lie above the federally inspected category and thus lead to their conclusion that cows comprise a much larger percentage of nonfederally inspected than federally inspected slaughter.

In their third method (equations (4) to (6) p. 570), Keith and Purcell fit three linear regression equations "as a final test to determine if cow slaughter is the major component of nonfederally inspected commercial slaughter" (p. 569). They regressed annual nonfederally inspected cattle slaughter, 1950–73, on federally inspected steer, heifer, and cow slaughter, respectively. They found that

Table 1. Estimated Commercial Cow Slaughter Given Alternative Average Replacement Rates, 1950–64

Beef Replacement Rate	Milk Replacement Rate		
	0.27	0.25	0.23
	----million head----		
0.15	119.32	112.88	106.44
0.14	115.57	109.13	102.69
0.13	111.82	105.38	98.94

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numbers of federally inspected steers and heifers were not significant in explaining year-to-year variations in nonfederally inspected slaughter, but numbers of federally inspected cows were. They conclude that "the coefficients and t-test statistics appear to support the two previous analyses" (p. 570). Whether such conclusions can be drawn from these data is highly questionable.

For whatever insights can be drawn legitimately, whether in confirming estimates of the percentage of cows in nonfederally inspected slaughter or in simply measuring correspondence between data series, we verified Keith and Purcell's results by refitting the three equations using the same data. However, the error terms in each equation have high levels of serial correlation. The Durbin-Watson statistics are .279, .291, .279 for their equations (4), (5), and (6), respectively. Hence, the regression coefficients reported by Keith and Purcell are inefficient and their variances are negatively biased, thus underestimating the confidence interval. In order to obtain efficient estimates of the coefficients, we applied the Cochrane-Orcutt first-order autoregressive model with the following results:

$$SLAT = 8408.64 - \underset{(1.86)}{.2161}\,STR - \underset{(-3.70)}{354.96}\,TIME$$

$$R^2 = .85, S = 415.3, \rho = .84$$

$$SLAT = 9058.61 - \underset{(1.83)}{.4254}\,HEIF - \underset{(-3.58)}{375.00}\,TIME$$

$$R^2 = .84, S = 417.5, \rho = .82$$

$$SLAT = 9170.41 + \underset{(3.18)}{.3777}\,COW - \underset{(-3.36)}{317.47}\,TIME$$

$$R^2 = .88, S = 365.9, \rho = .88$$

where $SLAT$ is commercial slaughter not federally inspected, STR is federally inspected steer slaughter, $HEIF$ is federally inspected heifer slaughter, COW is federally inspected cow slaughter, $TIME$ is time, S is standard error of estimate, and ρ is autocorrelation coefficient. Numbers in parentheses are t-statistics.

The magnitude of the coefficient on the cow variable is lower than that estimated by Keith and Purcell, while the coefficient on the steer variable is similar, and the coefficient on the heifer variable is much larger. T-ratios for all livestock variables are higher than previously estimated; the t-ratio for the cow variable is above 3 while the t-ratios for the other livestock coefficients are only a little less than 2.

With no obvious reason for estimating three separate equations (except possibly for multicollinearity), we combined all three livestock variables into one multiple regression equation with these results:

$$SLAT = 7393.45 + \underset{(.911)}{.1000}\,STR + \underset{(1.12)}{.2390}\,HEIF + \underset{(2.54)}{.3150}\,COW - \underset{(-3.76)}{385.11}\,TIME$$

$$R^2 = .89, S = 360.7, \rho = .85.$$

The coefficients on the cow variable in the above equations reveal that variations in federally inspected cow slaughter were associated with variations of about one-third (as contrasted to Keith and Purcell's estimate of about one-half) the magnitude in nonfederally inspected commercial slaughter. Although not statistically significant at the 5% level, variations in federally inspected steers and heifers were associated with variations, respectively, of one-tenth to one-fifth and one-fourth to two-fifths of the magnitude in nonfederally inspected commercial slaughter. We will not attempt to draw any conclusions concerning percentage of cows in nonfederally inspected slaughter from the statistical equations.

Changing the period of analysis to the years 1956 to 1975, we reapplied the arithmetic and statistical methods. For method 1, cows were estimated to represent 19% to 39% of nonfederally inspected slaughter;[1] for method 2, cows were estimated to represent 11% to 35% of nonfederally inspected slaughter. For method 3, the coefficients of the cow variables were .2579 and .2695, thus implying that variations in federally inspected cow slaughter were associated with variations of only about one-fourth the magnitude in nonfederally inspected commercial slaughter. Between 1956 and 1975 cows actually comprised 22.1% of the federally inspected slaughter. Consequently, our application of methods 1 and 2 provides estimates of the percentage of cows in nonfederally inspected slaughter that bracket the percentage in federally inspected slaughter.

In conclusion, the findings of Keith and Purcell are very sensitive to the underlying assumptions of their analyses. Since both their estimates and ours vary widely, the need for more precise data on nonfederally inspected commercial slaughter is evident. However, with the current data void, the hypothesis that the percentage of cows in nonfederally inspected slaughter is the same as in federally inspected slaughter has not been convincingly refuted.

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[1] Keith and Purcell indicated that method 1 could be used only back to 1965, because data on heifers intended for replacement were unavailable prior to that date. However, data for this USDA data series were actually collected beginning only in 1970 and were computed backwards by formula to the year 1965. This same formula was used here to extend the data series back to 1956.

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A Note from the Editor

V. James Rhodes

The change in editorship of the *Journal* may raise questions in the minds of members in their dual roles of potential readers and authors. These questions likely are due more to uncertainty regarding review and publication policies than to the general orientation of the *Journal*. This note will address three topics over which editors are presumed to exercise some license: quality of publication, product mix, and editorial procedures.

Quality depends more upon the authors and the reviewers than upon the editors, but we take our responsibility seriously and intend to maintain the same high standards of quality the *Journal* has previously enjoyed. We appreciate receiving finished papers and informative reviews. The latter can contribute greatly to *Journal* quality. If the review contains observations that can improve the paper we generally will request a revision, even if the piece as initially submitted is of acceptable quality.

The content mix of the *Journal* has been a source of concern for a decade or more. Many of those criticisms made to the Smith Committee some time ago were surfaced again last year by the Hurt Committee and also by the Extension Committee. We are sympathetic with the idea that all members of the profession should find the *Journal* of interest. On the other hand, members must be prepared to make some investment in understanding what has become a very diverse subject matter in the agricultural economics area.

We are open to a broad range of subject matter. We will be as receptive to the manuscripts of the perceptive essayist, careful analysts of applied problems, testers of propositions from the theory as to the tool makers and theorists. We will publish more papers on policy and on results of applied research if we receive quality pieces. The unfortunate fact is that we receive very few papers—of any quality—in those areas in which there are the most complaints of too little publication.

During our editorship, we will commission a few papers in areas of clear contemporary interest. We will also seek a few tutorial papers which synthesize the present state of the art. These latter papers should be useful for class assignments as well as for up-dating non-specialists. In short, they should make new developments in theory and method accessible and useful to a large number of our potential readers.

However, the principal content of the *Journal* will continue to be unsolicited papers, so the product mix will depend upon you. We want in every way possible to encourage a broad range of intellectually stimulating papers. For example, Kelso's Fellows Lecture stirred many comments at San Diego; are thoughtful essays on that lecture being prepared for the *Journal?* If you have a piece that is well done but you are uncertain about its appropriateness for the *Journal*, do not hesitate to submit it. At a minimum, you will receive a careful review and some comments which may provide a basis for improving the manuscript.

We acknowledge with gratitude the assistance of William Tomek and his staff in providing us an excellent record system and set of office procedures. We expect to change little, if anything, in those general procedures and in the *Journal*'s format.

A few words about our typical procedures may be helpful to authors. Two referees are used by the editors to assist in their evaluation of the professional contribution of a manuscript. Our instructions to reviewers, which are almost identical to those of the past six years, are available upon request. The experience is that some degree of revision is asked of almost all manuscripts. Some manuscripts become "rejected" solely because the requested revision is never made. Substantially revised manuscripts are frequently reviewed by a third party and also by one of the original referees.

The normal flow of twenty-five new manuscripts per month plus a comparable flow of reviews and revisions prohibits extended editorial consideration of a manuscript or the giving of substantial assistance to an author. Nevertheless, we recognize our own fallibility, and authors who believe the review sequence to have been improper or unfair should feel at liberty to state their cases. At the same time it is apparent that we, as authors, while intimate with the technical aspects of our papers, may be among the least objective of all those involved in the review process.

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This note benefited from the counsel of associate editor Stanley R. Johnson. The author is responsible for the final content.

Publications

Books Reviewed

Anderson, Jock R., John L. Dillon, and J. Brian Hardaker. ***Agricultural Decision Analysis.*** **Ames: Iowa State University Press, 1977, 344 pp., $17.50.**

"The neoclassical theory of the firm with its assumptions of certainty and linear utility is inadequate for normative analysis of risky production where preference for profits is nonlinear." This statement and an assertion that economics training does not adequately reflect that most managerial decisions involve elements of uncertainty tell us why Anderson, Dillon, and Hardacker have written a textbook. It is a volume directed at both students and practitioners who desire to include risk aversion and uncertain outcomes in their agricultural production analyses.

The managerial decision theory topics come in the first half of the book. The second part gives in-depth treatment of four approaches to more specialized problem areas—production under risk, whole-farm planning under risk, investment appraisal, and decision analysis with preferences unknown. The beginning chapters present the subjective probability, revision of probabilities by Bayes theorem, and utility components of decision problems. A major contribution of this part of the book compared with other managerial textbooks is the rigorous presentation of various utility functions. An intuitive justification for Pratt's measure of degree of risk aversion is presented and used to evaluate various utility functions. There is a comprehensive survey of methods for elicitation of subjective probabilities and preferences. This draws on the authors' own experiences in surveying and advising Australian ranchers. A theme that comes through fairly quickly is that even a sparse set of data points on uncertain events and preferences can aid decision making.

Perhaps the most significant contribution comes in the second part of the book in the authors' effort to synthesize the many research approaches to risk problems. The authors provide a real service in chapter six by carefully showing how the optimality conditions of the theory of the firm change with marginal changes in risk. They begin with a one-input, one-product model of expected utility maximization with uncertain product price and uncertain yield response. They derive the mean and variance of profit in general terms. By examining the input derivative of the utility function, they are able to show rigorously that the optimal level of input use, holding price risk constant, is less than the value of the marginal expected product of the input. They introduce a term labled REDQ, or the rate of utility substitution between the expectation and the variance of profit. By examining how input levels affect both REDQ and marginal changes in risk, they show with the aid of several diagrams how risk affects optimal input and output levels. The richness of this moment method is developed further by indicating how higher moments can be included, how other utility functions can be used, and by completing a maize-nitrogen example. They do not choose to present the mean-preserving spread risk concept, nor survey its use in many recent theoretical models of risk impacts on the firm.

The other three research chapters are characterized by completeness and use of examples to illustrate and compare methods of analysis. An extensive annotated bibliography follows each chapter (some 450 references in all). The whole-farm planning chapter is developed by solving a simple three crop and four resource restraint problem by five different risk programming methods. Uncertainty is introduced into product prices, resource constraints, and input-output coefficients. The crude state-of-the-arts of stochastic, sequential programming with a nonlinear utility function is illustrated. The authors claim that even a crude inclusion of risk by Monte Carlo methods is better than ignoring it.

The final chapter treats the relatively new, stochastic dominance approach to risky decisions. The definitions, realistic agricultural examples, and figures lead one through first, second, third, and convex stochastic efficiency. The message that one is left with is that there are some advantages to the stochastic dominance methods, but outcomes are sensitive to the location of the tails of probability distributions. This may lead economists to encourage agricultural scientists to set up experiments under a wider range of environmental conditions.

Probably the most serious shortcoming of the book is the authors' emphasis on methods for assessing and bringing data to bear on the problem, rather than presenting models which will aid understanding the nature of the world that generates risk problems. Except for minor treatments of portfolio theory and the effect of marginal changes in risk on demand for factors, and output decisions, there is little link to positive economics. Little attention is given to risk management resources such as insurance, pesticides, storage, forward contracts, or leases. Neither demand side risk problems nor policy analysis are given much attention. Some recent research efforts provide evidence that part of the behavior that has been attributed to risk in agriculture is traceable to a closer accounting of relative factor prices, enforceability of contracts, or costs of information. This research is not evaluated by the authors.

The authors define and use the concept of value

of information in the narrow Bayesian context. It would have been helpful if they had developed further the ideas of some of their previous work on value of experimentation. It seems that a large part of the value of information depends upon its public good nature, its cost of transformation to local conditions, and the direct utilization costs such as analysts and management time. When there are alternative information sources providing information with different features and different time rates of deterioration, then the value of information is much less clear. A deeper understanding of some of these cost issues might help us understand why the utilization of formal decision models is limited in much of agriculture.

With these qualifications, this book is heartily recommended. The authors have given freely of their experiences and insights. This book's encyclopedic nature and excellent index will make it a valuable reference for agricultural economists. It should be a useful guide to future cohorts of managers and economists who risk to understand risk.

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Arndt, Thomas M., Dana G. Dalrymple, and Vernon W. Ruttan, eds. *Resource Allocation and Productivity in National and International Agricultural Research*. Minneapolis: University of Minnesota Press, 1977, xxvii + 617 pp., $25.00.

This substantial volume stems from a 1975 conference sponsored primarily by the Agricultural Development Council. It comprises twenty-nine papers whose authors represent a significant proportion of the internationally known human capital dedicated to administration and economic research in agricultural development.

Arndt and Ruttan (chap. 1) introduce the volume with an excellent overview, integrating the conclusions of the following chapters into an essay warranting a close reading, irrespective of the reader's interest in the chapters that follow. These are grouped in six major sections: productivity of national and international research systems; organization of the international system; a somewhat catch-all section on organization and management of research systems; the relation of economic and social factors to research resource allocation; and a final section on the future of the international research system. The final chapter in each section is intended as a capstone piece, where some of the issues are synthesized and extended.

As with any collection of this magnitude the resulting product tends to obey what we might term the "Inverse Law of Sampling;" i.e., the larger the sample size, the greater the variance. This result is at the same time an attractive feature (widening the potential audience to include a broad range of administrators and social scientists) and a drawback (with many papers of lesser concern to those with specialized research interests). However, the capstone pieces provide the reader with an opportunity to grasp many of the issues contained in each section. Particularly noteworthy are those by Hertford and Schmitz (chap. 6) and de Janvry (chap. 26). The former provides a summary of the tools so widely used in estimating the social benefits of research, and concludes with some valuable suggestions for extensions to the standard analyses; de Janvry presents a conceptual framework which captures some of the dynamics of technical and institutional change. He views such changes as public goods whose supply is partly a response to the clamorings of potential gainers and losers. The chapter evolved from de Janvry's role as a discussant. Further development will hopefully enrich the linkage between the theory of public goods and the innovation hypotheses of Hayami and Ruttan, Binswanger (chap. 25), and Kislev (chap. 10).

The volume represents, at least in part, a sequel to the 1969 Minnesota conference on Resource Allocation in Agricultural Research (Fishel). But the words "productivity" and "international" are included in the title of the present volume. There appears to have been some waning of interest in the search for formal algorithms for research resource allocation. Perhaps the almost universally high rates of return constitute testimony to the perspicacity of the "considered judgments" model of the pragmatic research administrator. In any event, the present volume lays more stress on *ex post* evaluation with all its attendant trials and tribulations.

The international perspective is added in at least four dimensions. First, the nature of research organization and management in four countries (Brazil, Japan, U.K., and U.S.A.) is discussed, giving the reader the opportunity to compare strongly centralized with more fragmentary research structures. Second, the returns to research investments are analyzed for Colombia, India, Japan, and the United States. Third, the role of the international research centers becomes a pervasive theme of the volume, and their conception, birth, and growth to adolescence is chronicled. In this regard the two chapters by Sir John Crawford (chaps. 11 and 29) reviewing the development of the international research system and reflecting on its future are particularly valuable. They provide access to materials and insights from the Consulative Group (CGIAR) which have not had widespread dissemination. Similarly two chapters by the directors of the first generation international centers (chaps. 12 and 13) conveniently summarize material which will be of value to those wanting to improve their understanding of the centers' role. Finally, the international dimension is further enhanced by the evaluation of wheat and rice research by Dalrymple (chap. 7), and the analysis by Evenson (chap. 9) of the international diffusion of research findings. Despite the problems of measurement and lack of data, the

international flavor of the volume might perhaps have been enriched by drawing on the first-hand experience of some of the participants in non-market economies.

For this reviewer, a disappointment of the volume (and implicitly the conference) is that the impact of research and its attendant technological change on income distribution and nutrition receives such scant attention. This neglect is somewhat puzzling in view of the upsurge of concern by the international donor community for equity issues, so prevalent in the early years of this decade. At times, the volume has an air of technocratic sterility—models grind, numbers churn, and derivatives equate, while poverty, disease, and malnutrition persist. That the twain might meet seems more a matter for happy coincidence than a subject which value free objectivity need confront. Pinstrup-Andersen and Franklin (chap. 20) do provide a useful clarification of means and ends; Mellor (chap. 23) discusses the impact on income distribution in his essay on the multiple goals of research resource allocation; de Castro and Schuh (chap. 24) consider the division of social benefits between consumers and producers in their framework for *ex ante* decision-making, and Schultz (chap. 28) briefly addresses the impact of research on personal income distribution in the only chapter related to broader issues of economic policy. But all these are relatively isolated instances of what might have been a most timely and relevant thrust. While many studies have provided a breakdown of the gross social benefits between consumers and producers, some attempt to examine the impact on the personal distribution of income in both the urban and rural sectors would provide additional information for both assessing and planning programs of agricultural research.

That a sampling from such a rich and diverse menu should reflect the tastes of this reviewer is inevitable; failure to mention all the contributions should in no way be read as any implicit criticism. But the need for such apology will be the less if the reader has been tempted to sample for himself from what must undoubtedly become a significant point of reference for future study of international agricultural research and development.

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Hayami, Y., and V. W. Ruttan. *Agricultural Development: An International Perspective.* Baltimore, Md.: Johns Hopkins University Press, 1971.

Downing, Paul B., ed. *Local Public Service Pricing Policies and Their Effect on Urban Spatial Structure.* Vancouver, Canada: British Columbia Institute for Economic Policy Analysis, University of British Columbia Press, 1977, xvi + 461 pp., $9.95.

With the expansion of urban areas, the spatial pattern of urban development and the problems of local public finance have emerged as dominant policy issues. The interrelationships between these two issues are, however, too often neglected. Urban models typically pay scant attention to the financing of services (Evans 1974), while the interest in pricing public services usually focuses more upon its revenue raising and demand constraining potential than its effects on spatial structure (Harris and Seldon 1976, Mushkin 1972). This book does not bridge these two approaches to the study of urban areas, being written chiefly from the applied public economics perspective; but it does provide evidence and insights as to the linkages which students of both fields will find valuable. While recognizing and appreciating the allocative merits and distributional questions associated with the pricing of public services, the papers in this volume eschew these issues to concentrate instead upon the effects of alternative pricing mechanisms on the urban spatial structure and the cost of supplying utility-type public services. The theme of the book is to examine in this context the consequences of failing to charge each consumer of a public service a price closely approximating the cost of providing that service to him. The cross-subsidization of consumers which otherwise results, and is believed to be widespread in practice, is generally contended to benefit low density-high service cost areas at the expense of high density-low service cost areas and thereby promote excessive urban sprawl and public service costs.

In examining this issue the papers in the book are organized into four topical groupings followed by the editor's brief summary and assessment. The four major divisions discuss (*a*) basic issues, (*b*) evidence of spatial factors causing variation in public service costs, (*c*) institutional influences on public service supply and finance, and (*d*) applications of pricing and recoupment alternatives.

The introductory section is particularly well done and will be appreciated by those seeking to become acquainted with the elements of the public service pricing-spatial organization problem. The rationale for marginal cost user charges is clearly outlined and the effects of alternative pricing mechanisms upon spatial organization simply illustrated. Despite their allocative advantages and their still considerable potential as a source of revenue to financially pressed local governments, it is noted that there are many practical difficulties impeding the acceptance of greater and more refined user charges.

The second set of papers presents evidence of how variations in density and/or distance effect the costs of a wide range of public services. Considerable differences can result. For example, the annualized cost of providing what might (other than for the failure to include roads and transportation) be considered a normal complement of public services to single family dwellings in areas of one unit per acre is estimated to be approximately 50% greater than to areas with five units per acre and about twice as costly as their provision to walk-up apartments with densities of fifteen to thirty units per acre. Unfortunately typical differences in the allocation of costs among housing types are not presented so that the extent of cross-subsidization is not evident. The paper reporting on the effects of customer density upon electrical distribution costs is more noteworthy in this respect. First, it is an empirical study of an actual case rather than analysis based heavily on hypothetical situations. Second, not only are economies associated with consumer density reported but the incongruity between the pattern of costs and the existing declining block rate structure is discussed, albeit briefly. This reader was disappointed, however, in this and other papers in this section because, while presenting evidence of nonoptimal public service pricing, there was only one attempt (a model of urban roads) to determine the nature and extent of its effect upon the urban spatial structure and to predict the improvement to be expected from alternative pricing mechanisms. Even in that instance the implications are limited and will only be evident to the diligent reader. Generally, the simultaneity of the public price-spatial structure relationship is not fully developed nor are the implications fully pursued. Instead, one is left to speculate as to the significance of whatever cross-subsidization appears present and its ultimate impact on the spatial pattern and service costs of the city.

The papers concerned with the effects of various institutional systems upon the supply and financing of public services are more satisfying as their discussion extends explicitly to the implications for urban spatial structure. These are primarily theoretical papers dealing with the influence of different political structures and the effects of alternative arrangements for public service supply and financing on location. They show that the spatial pattern of urban development can be affected by the fiscal choices available to fringe areas—free ride, depend on private supply, provide their own services, contract with another jurisdiction (the result depending upon the presence of monopoly power), or unite with a larger service area. One paper on the consolidation of local public services depicts a model of a growing urban area where, because of the nature of service costs, different local choices are attractive at different times. Ultimately, the urban region emerges as an economic federation of overlapping service areas.

In focussing on the application of pricing and recoupment alternatives, the fourth section examines the objections to implementing marginal cost user charges in less developed countries and surveys the experience with betterment taxation in Europe and Asia. Though interesting, the emphasis of these papers is likely to leave many readers pondering the role of alternative pricing or supplying systems on this continent. This section could have been strengthened had it been supplemented by studies of the effects of alternative institutional arrangements and/or pricing mechanisms like Ahlbrandt's examination of the costs of fire protection under public and private provision but also tuned to the spatial context (Ahlbrandt 1973).

This collection of papers provides an organized survey of the study on the relationship between public service pricing practices and urban spatial structure. As such it deserves examination by persons in a variety of disciplines interested in urban spatial organization, for consideration of the ideas discussed in it are likely to enhance the understanding and stimulate the thinking of most. Many readers are, however, likely to be struck by the considerable variation in the level of sophistication and the degree of originality among the papers. Such a range is admissable as synthesis and review is an essential ingredient in what is interpreted to be a state of the art volume, but it does mean that the appeal of particular papers will depend very much on the reader's background. One concluding point must be made. Although after reading this book one's understanding and appreciation of the relationships between public service pricing and urban spatial structure is enhanced, it is obvious to the reader, as to the volume's editor, that the actual impact of cross-subsidization on spatial organization remains uncertain. The responses to alternative price systems are not determined. Rather, evidence of potentially distorting influences is presented but the extent of the distortion is not documented. Indeed, does capitalization of the various gains and losses in the land market leave locational incentives similar to those which would exist under marginal cost pricing? No paper here addresses this issue. Reading this book should encourage researchers to pursue the many challenging questions which remain.

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Ervin, David, James Fitch, Kenneth Godwin, Bruce Shepard, and Herbert Stoevener. *Land Use Control: Evaluating Economic and Political Effects.* Cambridge, Mass.: Ballinger Publishing Co., 1977, 184 pp., $17.50.

This book is the tangible product of an impressive multi-disciplinary research and education project at Oregon State University, supported in part by the National Science Foundation and the Rockefeller Foundation. That a committee could produce a manuscript is a remarkable feat in itself. While chapters are predictably of uneven quality, the book in general is a credit to the many who contributed. Its stated purpose is to offer a framework for evaluating land use policies. The framework includes consideration of impact distribution and political acceptability, though neo-classical efficiency is the basic standard for comparison of land use control techniques.

Chapters 1 and 2 discuss the efficiency character of land use planning and policy. The inference is that public intervention in private land use choices should lead to more "efficient" use of land. Chapter 3 presents some empirical data on distribution of real estate ownership among income classes and identifies further distributional issues. It does not follow smoothly from previous chapters, but is useful on its own. Chapter 4 is a well-written treatment of socio-political issues, jointly authored by two political scientists. Each of the next three chapters is devoted to a certain technique of land control—zoning, zoning by eminent domain, and transfer of development rights. They are three very thoughtful, informative chapters. The eighth, and concluding, chapter attempts to draw the loose ends together with some observations about the appropriateness of efficiency standards to gauge improvement in land use decisions. Not surprisingly, land use policy rates at best a "marginal pass" on the efficiency test.

Several of the chapters in this ambitious text contain real insights into the nature of land use policy. Discussion of transferable development rights, for example, is almost worth the price of admission on its own. Unfortunately, however, the whole seems to come out as somewhat less than the sum of its parts. The effort to bind the package together within some sort of conceptual framework does not quite come off. The authors sensed this difficulty—the concluding chapter begins:

> The analysis of the preceding chapters may leave the reader somewhat discouraged. We have shown that private land use conflicts can occur and that society in general may have to accommodate to a set of suboptimal efficiency and distribution outcomes.

Therein lies the difficulty with this book. The effort to impose a normative neo-classical straitjacket on the process of allocating rights to land does not contribute to the reader's understanding of the process. The authors have erected an impossible standard, "optimum use," and observe that public rules like zoning may neither achieve optimum, nor be "equitable." I have trouble with those value-laden terms. They impose formidable constraints on analysis of the complex political and economic circumstances surrounding public direction of land use choices. I have come to the conclusion that in the "real world" of policy nobody (except perhaps a few economists) really cares about economic efficiency of land use. While we as a total society may have some overriding interest in directing land use consistent with comparative advantage, using "efficiency" to appraise specific policy tools is just not helpful. I would agree that for some interest groups, "efficient land use" is a handy symbol for policy choices supporting their interests. The timber industry, for example, may carry the efficiency banner to support public decisions that increase cutting rights on public forests. Reallocation of rights to permit more cutting on productive forest land assumes that opportunities forgone in that decision are more than offset by economic returns generated. There are many environmental groups that would disagree rather vigorously with the value scheme leading to that "efficient" solution. The point is that any allocation rule implies a distribution of rights among those participating in the allocation process. Changing the allocation rule implies a redistribution of rights, deemed more efficient by the gainers and less efficient by the losers. Thus, the initial allocation of rights is a crucial aspect of the decision rule, whether a market or zoning ordinance. In land use policy, as in all areas involving non-marketed goods and services, efficiency and equity are matters of opinion.

Ervin and his colleagues venture the judgment, for example, that zoning by eminent domain and transfer of development rights are "better" or more equitable techniques than pure zoning because land owners are compensated for loss in development potential. But who says they had those rights in the first place? There is nothing sacrosanct or absolute about fee simple ownership. Zoning boards redefine ownership every day. Perhaps the equitable or efficient approach would be a 100% tax on unearned increment in land value. The important policy questions with any institutional change concern how the costs, in dollars and discretion, are distributed. Adding efficiency to the discussion as some superhuman normative goal contributes nothing as a guide to choice. Property rights and institutions are central to the economics of land use, not exogenous.

Despite these somewhat philosophical points of contention, I found the book well worth reading. In terms of their stated objective—to create an evaluative framework for land policies—I feel they have

missed the mark. It is not a comprehensive treatment of land use controls, as implied by the title. And insights about the three techniques studied came in spite of the analytical model, not because of it. The authors seem uncomfortable with the efficiency standard but could not quite articulate the source of their discomfort. Still and all, the subject matter content is excellent. The book is a useful contribution to a growing literature on the economic implications of alternative public mechanisms guiding the use of private land.

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Reference

Kelso, Maurice. "Natural Resource Economics: The Upsetting Discipline." Fellows lecture, AAEA Annual Meeting, San Diego, Calif. 1977.

Halcrow, Harold G. *Food Policy for America.* New York: McGraw-Hill Book Co., 1977, x + 545 pp., $19.50.

Halcrow has produced an informative book on past and present U.S. policies related to food and agriculture. It is not simply a revision of his earlier book on agricultural policy, but a completely new text dealing with a broader range of topics than is to be found in most existing books on agricultural policy. About 60% of the text is devoted to the traditional subject-matter areas of agricultural policy including a discussion of aggregate demand and supply relationships, the history of agricultural legislation, changes in technology, price or income-support and reserve policies, marketing orders, and the role which farm organizations have played in shaping past policies. The remainder of the book deals with such diverse topics as land use, conservation and tax policies affecting agriculture, the role of corporations in agriculture, farm labor, government credit, rural development, manpower training, education, and nutrition programs.

The author has succeeded in writing a book that can be read by just about anyone with an interest in food and agricultural policies, including undergraduate students with little or no previous exposure to economics. Factual material is presented in a straightforward and unadorned style. There is a notable absence of economic jargon or mathematical notation. In fact only two equations appear in the entire book and one of these is the universal soil loss equation!

The author's approach is mainly historical and prescriptive. The historical antecedents of existing programs are usually reviewed at the beginning of each section. This is followed by a summary of the achievements and limitations of such programs, and, finally, by a concluding section in which the author presents his own views on what needs to be done. He comes down clearly on the side of more government intervention or assistance in such areas as land-use planning, conservation, education, and rural development. He also favors integrated planning of food policies, government-held grain reserves, additional funds for research in nutrition, restrictions on mergers in the food industry, and limitations on tax-loss farming.

Halcrow has done his homework thoroughly and provides an abundance of citations. In one chapter alone, there are 139 footnotes. But not everyone can be expected to share the author's passion for details. Many readers will find the descriptive information excessive, both in the text and in some of the tables. It is not clear, for example, why time-series data on acreage, yield, production, exports, and other information relating to such crops as tobacco, cotton, and feed grains were included, in some instances for periods as long as forty-five years. Few readers are likely to take the time required to decipher some of the more complex figures included in the chapter on nutrition. Readability could have been improved by an editor with a firm hand.

The typical undergraduate student's low tolerance for history (or at least anything which occurred before about 1970) is likely to limit its popularity as a textbook. Instructors who read the text will be much better informed and able to place existing policies in their historical context, but the interest of most students will flag before the assignment is completed.

Those who prefer an analytical approach will find the book somewhat disappointing. Tools of analysis are not given great emphasis, nor are they used to compare the consequences of alternative policies. The concept of supply elasticity, for example, is treated very briefly and with a lack of precision. The author fails to make clear that elasticity refers to percentage relationships, not absolute changes in quantities and prices (p. 133). Nor does he distinguish between movements along a supply curve and a shift in the curve induced by changes in factor prices, technology, etc. Very little use is made of supply and demand relationships in analyzing the consequences of price policies or marketing orders.

There are few obvious omissions or errors of fact or interpretation. One of the exceptions occurs on page 323, where he refers to a world wheat storage scheme of 20 million bushel capacity rather than 20 million tons. In discussing meat quotas, the author fails to point out that the threat of quotas has been used as leverage to compel exporting nations to institute "voluntary" export controls (p. 272). The role of competitive forces in pricing most fruits and vegetables is underemphasized (p. 287). One of the distinguishing features of U.S. farm policies which is not discussed is the discriminatory nature of support programs; that is, why the prices of some commodities have been supported while others have not.

The book can be recommended as a comprehensive reference on U.S. food and agricultural policies and also as a text for those who prefer an historical or institutional approach in teaching policy courses. Even for those who do not, it can serve as a useful supplement to existing texts in such areas as land, conservation, human nutrition, and food policies. The discussion of land use and conservation policies is particularly good.

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Johnson, Ralph W., and Gardner M. Brown, Jr. *Cleaning Up Europe's Waters. Economics, Management, and Policies.* New York: Praeger Publishers, 1976, xvi + 313 pp., $26.50.

In the last few years there has been a large body of theoretical literature in environmental economics. Recently, the environmental policy pursued in the United States has received increasing attention. There has, however, been an almost complete lack of information about the European experience in environmental policy (except for the Ruhr associations), and therefore of a comparison with environmental policy in the United States.

Johnson and Brown's book is mainly devoted to the first task, namely, to present an analysis of environmental policy in European countries. Where possible, quantitative (but not econometric) information is supplied.

The authors, an economist and a lawyer, have written an excellent book. It combines economic aspects, institutional details, and a look at the political processes behind the policies pursued by the individual countries. The presentation is lively, and reading is made easy because the main lines always remain clearly visible: (*a*) the discussion of the appropriate jurisdiction for water resource management with respect to area and subject matter; (*b*) the analysis of the functioning of, and the reasons for adopting and rejecting, effluent charges; and (*c*) the study of the role of subsidies. The (not too strong) trends towards comprehensive management and towards adopting effluent charges is well documented. As case studies, five highly industrialized market economies are selected: France, the Netherlands, West Germany, Sweden, England/Wales, and, as a contrast, one less developed socialist (planned) economy, Hungary. It is noteworthy that the typically market oriented system of effluent charges is used, among others, in Hungary; while standards only are used in Sweden. Subsidies are used in all countries, but least strongly in Hungary, most strongly in France. It is suggested that the main function of subsidies is to overcome the opposition of owners of private property rights to environmental policy, and that, therefore, the less subsidies are needed the larger the public sector (i.e., the weaker private property rights). It would be worthwhile to test this interesting proposition more thoroughly.

Johnson and Brown clearly state that they have a value-laden preference for the polluters' pay principle and for the effluent charge (a view shared by most economists), as well as for comprehensive management. The latter preference is less convincing. The book does indeed stress too little the disadvantages going with centralization. A recurrent theme in the book is that in Germany there is little information about environmental policy, plans, and intended future action. The authors do not realize sufficiently that this is a necessary consequence of a federal system in which information is not centralized because it need not be centralized. This makes research difficult. The outcome is not necessarily worse; possibly it is better, as suggested by the economic theory of federalism. The authors are in this respect somewhat inconsistent: they complain about the insufficiently comprehensive planning, especially in Germany; give, at the same time, a very positive account of the Ruhr associations; and state that it is unlikely that on the national level a similarly good solution would be possible. They even mention that the good functioning of the Ruhr associations might be hampered by effective national legislation. Positive examples such as the Ruhr associations (or TVA in the U.S.) unfortunately seem to have little effect on practical policy. An effort is made to explain this, as well as why some countries adopt and others reject systems of effluent charges, but the authors state frankly that they have had little success. It may be that the "public choice" approach would yield more conclusive results.

There is little to criticize specifically in this book. A somewhat stronger reliance on scientific publications, instead of interviews and official documents, would have increased the depth of analysis. There are some spelling mistakes in French and Swedish words, which should have been avoided.

On the whole the book fulfills its goals admirably. It is useful for various purposes: it provides information to researchers, it can be employed for teaching, and it may give clues for improvements of practical environmental policy.

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Maxwell, James A., and J. Richard Aronson. *Financing State and Local Governments.* 3rd ed., Washington, D.C.: Brookings Institution, 1977, xvi + 290 pp., $10.95, $4.95 paper.

In an attempt to provide students and interested citizens with a nontechnical analysis of state and local finances in the United States, the late James Maxwell collaborated with J. Richard Aronson in producing a third edition of his *Financing State and Local Governments*. Significant shifts, both in the

amounts and types of intergovernmental transfers and state-local debt and in awareness of the potential problems in state-local retirement systems over the 8-year period since the publishing of the second edition, created the need for a new edition. These shifts are reflected in the new edition by a greatly expanded treatment of federal and state transfers to lower levels of government and by the addition of an excellent short discussion of the structure of state-local retirement systems and of the important issues in designing such systems.

The first chapter of the book gives a historical overview of the development of the federal system and demonstrates that while many traditional state-local services (education, public welfare, highways) are still provided by state and local governments, the large and growing share of these expenditures is financed by federal dollars. This is followed by a chapter describing the diversity among states both in their state-local expenditure patterns and in their revenue structures and fiscal capacity.

The next seven chapters describe in some detail the various sources of revenue of state and local governments. One chapter apiece is devoted to federal and state intergovernmental transfers.

Chapters 5 and 6 examine state taxes. The progressivity of the overall tax system and of the relative merits of sales taxes and income taxes as sources of state revenue are discussed in chapter 5.

The property tax, the traditional mainstay of local governments, is discussed in chapter 7. After noting that its relative importance to local governments has declined over the past half century (from providing 74% of the general revenues of local governments in 1927 to providing only 37% in 1973), the authors focus on the questions of incidence, economic effects, problems in administration, and the state role in property tax reform. Chapter 8 outlines the nonproperty tax and nontax revenues of state and local governments. The examination of state and local debt in chapter 9 documents the tremendously rapid growth of this debt since World War II. It also examines the economic effects of the exemption of interest on this debt from income taxation and of the constitutional and statutory limitations on debt on the growth of nonguaranteed bonds.

Chapter 10 is a discussion of three issues related to budgeting in state and local governments: earmarked revenues, retirement systems, and capital budgeting. The final chapter recapitulates the trends identified in earlier chapters and discusses projections of future prospects.

Maxwell and Aronson's book has much to commend it for use as a supplementary text in undergraduate courses in public finance or as an introduction to the mysteries of state-local finance for the interested citizen. The book provides a comprehensive overview of the subject; it avoids economic jargon; and, it provides a very good historical perspective on government finance since the origins of the republic.

The chapters on the major grant programs of the federal and state governments present information which is not readily available elsewhere. The sections on capital budgeting, the economic effects of the tax exemption for state and local debt, and the structure of the state-local retirement systems are excellent introductions to complex subjects. The numerical examples used to explain these concepts are easy to understand, yet point out the significant issues. The bibliography provides a concise listing of data sources, periodicals, and studies on special topics in state and local finance which guide the interested reader to good sources of further information.

There are, however, two limitations of the book which deserve mention. The first is the lack of an explicit framework for analyzing the desirability of alternative schemes of raising revenues and of alternative allocations of responsibility among the various levels of government. This by itself would not be a serious flaw in an introductory book were it not for the authors' rather frequent and unqualified prescriptive statements about what "ought" to be or what states "should" do; for example, "the present clutter of grants and shared taxes that make up state intergovernmental payments is an untidy accumulation that should be consolidated" (p. 91). While their prescriptions may be appropriate and consistent, the lack of explicit framework makes it difficult for the reader to determine this.

The second shortcoming of the book, in my view, is the authors' apparent unquestioning acceptance of the conventional wisdom which deplores the existence of small and overlapping units of government. "An important characteristic of many local governments is the overlapping of three or four—and occasionally seven or eight—layers of governmental units in the same geographic area. In terms of public finance, the diversity and proliferation seldom make sense" (p. 77). Further, the present variation in performance among local governments "exceeds acceptable limits" (p. 79). While there may be some merit in this position, it seems to me that the arguments and empirical work of the public choice theorists (which suggest that "bigger and fewer" is not necessarily more efficient and that diversity in performance can reflect citizen preferences) deserve more than the five-line footnote on page 80.

Maxwell and Aronson's third edition of *Financing State and Local Governments* provides, in spite of these shortcomings, an excellent introduction to the subject and should serve the intended audiences quite well. The limitations suggest that, as a textbook, it be used in conjunction with other books which provide an analytical framework and an appreciation of the insights of the public choice scholars.

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Tweeten, Luther, and George Brinkman. ***Micropolitan Development.*** **Ames: Iowa State University Press, 1976, ix, 456 pp., $20.00.**

The condition and direction of rural America have been a subject of intermittent policy interest since the founding of the American Commonwealth some 200 years ago. Over that period, opinions as to the nature of the problem, the policy instruments available, and the proper role of the rural sector in a changing society have varied with the size and condition of rural America. Today, with rural America experiencing more rapid population growth than the urban sector and given a renewed interest in the virtues of rustic lifestyles, new sets of convictions on the nature of rural problems and necessary corrective policies are emerging.

The need for separate rural policies ultimately rests on the assertion that rural needs differ from urban needs. Separate rural policies may be necessary to correct deficiencies at a point in time or because rural areas respond differently than urban areas to changes in aggregate conditions; e.g., compensatory education programs may be necessary to close the rural-urban education gap, or more rural educational facilities may be necessary to effect increases in the median level of education because of a widening of the rural-urban gap. Since specialized policies derive their raison d'etre from heterogeneities which preclude uniform policies, advocates of separate public policies for rural America must first demonstrate that rural problems differ in degree, kind, or vicissitude from their urban counterparts. These problems, of course, should be amenable to solution through policy intervention.

Luther Tweeten and George Brinkman have revitalized the term "micropolitan" to describe the uniqueness of rural America. The development goal remains the same: micropolitan or rural "development (defined as improving the well-being of people) requires a broader perspective than just an examination of open country and rural towns and must include cities of at least 50,000 population which serve as centers for trade, services, and jobs for hinterland residents" (p. vii). The book is intended to provide "a comprehensive look at rural development" and to serve a wide audience as "a classroom text, a book of readings, a reference, or as a guide to rural development practitioners and decision makers" (p. vii). The authors also seek to chart murky waters by attempting to "integrate literature on micropolitan development into a meaningful whole" (p. viii).

The book's fourteen chapters focus on four themes. The first three chapters provide an overview of rural America and briefly discuss the theory of regional economics. Chapters 4 through 6 discuss human resource issues, while 7 and 8 focus on the physical infrastructure. The book concludes with an extensive discussion of planning and financing rural development within national growth goals.

After the familiar litany of rural economic deficiencies—including rural incomes which are 79% of urban averages (1973); disproportionate poverty (41% of all federally defined poor persons in 1975); and deficient health care, education, and housing—the authors note that federal programs, instead of concentrating assistance monies in areas of greatest "need," provide urban areas with a disproportionate share of development funds. It is argued that federal spending patterns and agricultural policies have combined to encourage an urbanization and centralization of the nation's population, despite the deleterious consequences to both rural and urban areas. The need to correct rural deficiencies is necessary if citizens are to be able to effectively exercise an expressed preference for rural lifestyles.

If rural America is to be "developed" with the assistance of public policies, some notion of "optimal" development is mandatory. Tweeten and Brinkman review the variety of population ranges felt necessary to achieve efficiency in the delivery of services (depending on assumptions, the population range is 10,000 to 500,000, implying that 46% of the population is already well-situated), and argue for more efforts to assist towns and cities at the lower end of the size scale. The federal government, in conjunction with state and local authorities, is seen as the main force behind continued or altered rural development efforts.

In 1974, some 58.3% of all rural county residents 16 and older were in the labor force. These 27.3 million persons included only 3.1 million in agriculture, forestry, and fisheries but 6.5 million persons in manufacturing, 4.4 million persons in professional jobs, and 4.1 million persons in retail trade. Although less than 12% of the rural labor force is engaged in agriculture, discussions of rural labor problems persistently reduce to listings of farm labor issues. Tweeten and Brinkman are only partial exceptions; after noting that rural employment growth lagged behind urban expansion in the 1960s (although manufacturing employment increased fastest in rural areas), they turn to a discussion of farm operators, family labor, hired farm workers, and positions in agriculture for potential entrants. The agricultural focus is clear in the brief discussion of social welfare legislation (pp. 102–104). Rather than noting problems of enforcing minimum wage laws and safety standards in smaller rural establishments, of organizing the rural work force into trade unions, or of preventing "footloose" nondurable manufacturers from threatening to move employment opportunities again, the discussion centers on the issues of unemployment insurance and social security coverage for farm workers, the differential farm-nonfarm minimum wage, and the difficulty of organizing farm workers without a defined legal framework. The latter issues are not unimportant; but, in a discussion of the rural work force, they directly impinge on only one in 10 persons in the germane population.

Rural welfare is affected by physical facilities and services as well as opportunities for education and jobs. It is argued that most community services could be more efficiently delivered if local units were consolidated to achieve economies of size. Such consolidations, ipso facto, create pressures for population centralization; hence, the "advantages of consolidation must be kept in perspective" (p. 222). Industrialization is seen as one way to provide new jobs, although it is recognized that nonlabor force participants may be hurt by rising taxes to finance public services since industrialization often increases public service costs without providing attendant tax revenues.

The book concludes with an extended discussion of planning for rural development. Some of the discussion is unduly sophomoric, e.g., "the term 'community' is a group concept" (p. 260), "many resources are needed for community development" (p. 260), and "planning is the process of deriving a plan" (p. 287). Some of these concepts merely reflect the state of the underlying disciplines ("interpersonal communication is a word-of-mouth communication between two or more persons . . . [and] requires special attention to the relationship between sender and receiver" [p. 279] and some are of use to "development specialists" acting as "catalysts" and "change agents"); but one is left with the impression that the state of community development theory helps explicate its (acknowledged) limited achievements.

The authors move quickly from community development planning to economic planning, summarizing the elements of input-output analysis and its multipliers as well as (briefly) discussing the techniques of simulation and linear programming. Too little background is provided for those unfamiliar with the techniques, a problem inherent in summarizing a vast literature; but the book returns to its previous levels with a discussion and an example of a feasibility study. The penultimate chapter introduces the various sources of public and private financing for development projects, suggesting changes in everything from property-tax systems to revenue-sharing programs.

The final chapter on national growth policy is the strongest. For the first time, a truly integrative approach is used to relate rural conditions and their expected changes to national policies. Problems of interpretation persist (e.g., virtually no labor economist would argue that social welfare programs *generated* dual labor markets [p. 410]—only that some public policies may help account for their continuation); but the discussion of an array of topics, from physical infrastructure through school funding, is admirably related to national policies and programs. The book concludes by reiterating that public (and, in particular, federal) policies are largely responsible for current rural-urban disparities and that altered public policies are necessary to effect change after an era of rural neglect. Key proposals include a "comprehensive income maintenance program" to assure equity and use of public funds to encourage and direct private investment in order to ensure economic efficiency.

As a first systematic attempt to integrate a diverse field, the authors deserve praise for an ambitious initial step. Several themes point to areas urgently in need of more research, viz. rural labor force behavior, optimal social welfare policies in areas of low population density, the magnitude and distribution of benefits and costs accompanying alternative rural employment creation policies, and rural community decision-making structures. Tweeten and Brinkman have surveyed a vast literature and expressed opinions on a variety of topics of current interest.

Deficiencies remain at several levels. Coining a new term does little to identify the causes or suggest solutions to policy problems. For a book which seeks to integrate the literature on "micropolitan development," there is a curious absence of the alternative definitions of "rural" and what each definition implies for the current state and recent changes in rural America. Although the limitations of static taxonomies in a dynamic world are noted (e.g., "successful" population growth merely gets an area reclassified as urban, leaving the depressed, stagnant areas behind), their policy implications are not explored. Migration is viewed as a "loss" to sending areas (of nearly $20 billion between 1960 and 1970, p. 13), without making an explicit distinction between individual and area welfare. Finally, for an integrative book, the writing is often pedestrian, forcing the reader's ingestion of numerous statistic-laden paragraphs.

Tweeten and Brinkman deserve an accolade for an adumbration of a field which has long defied unifying efforts. It is the duty of others to fill in the gaps.

Philip Martin
University of California, Berkeley

Books Received

Anderson, Jack R., John L. Dillon, and J. Brian Hardacker. *Agricultural Decision Analysis.* Ames: Iowa State University Press, 1977, 344 pp., $17.50.

Anderson, Lee G. *The Economics of Fisheries Management.* Baltimore, Md.: Johns Hopkins University Press, 1977, xviii + 214 pp., $14.00.

Banks, Edwin M., and John A. Heisey. *Animal Behavior.* Chicago: Educational Methods, 1977, x + 200 pp., price unknown.

Beard, James B., Harriet J. Beard, and David P. Martin, eds. *Turfgrass Bibliography from 1672 to 1972.* East Lansing: Michigan State University Press, 1977, vi + 730 pp., price unknown.

Bunt, A. D. *Modern Potting Composts, A Manual on the Preparation and Use of Growing Media for Pot Plants.* University Park: Pennsylvania State University Press, 1976, 277 pp., $14.50.

Callahan, Philip S. *Tuning in to Nature—Solar Energy, Infrared Radiation, and the Insect Communication System.* Old Greenwich, Conn.: Devin-Adair Co., 1975, xxviii + 240 pp., $10.00.

Chou, Marylin, David P. Harmon, Jr., Herman Kahn, and Sylvan H. Wittwer. *World Food Prospects and Agricultural Potential.* New York: Praeger Publishers, 1977, xvi + 316 pp., price unknown.

Clawson, Marion, ed. *Research in Forest Economics and Forest Policy.* Washington, D.C.: Resources for the Future, 1977, xi + 555 pp., $8.95.

Cohen, Sanford, ed. *Issues in Labor Policy, a Book of Readings.* Columbus, O.: Charles E. Merrill Publishing Co., 1977, ix + 292 pp., $7.95.

Connell, John, and Michael Lipton. *Assessing Village Labour Situation in Developing Counties.* Delhi, India: Oxford University Press, 1977, 180 pp., $6.25.

Dasgupta, Biplab. *Village Society and Labour Use.* Delhi, India: Oxford University Press, 1977, vi + 229 pp., $6.95.

Downing, Paul B., ed. *Local Public Service Pricing Policies and Their Effect on Urban Spatial Structure.* Vancouver, Canada: University of British Columbia Press, 1977, xvi + 461 pp., $9.95.

Fussell, G. E. *Farms, Farmers and Society—Systems of Food Production and Population Numbers.* Lawrence, Ks.: Coronado Press, 1976, x + 332 pp., $15.00.

Glickmann, Norman J. *Econometric Analysis of Regional Systems—Explorations in Model Building and Policy Analysis.* New York: Academic Press, 1977, xi + 210 pp., $18.50.

Goldin, Augusta. *Grass: The Everything, Everywhere Plant.* New York: Thomas Nelson, 1977, 176 pp., $7.95.

Henshaw, Randall, ed. *Stagflation: An International Problem.* New York: Marcel Dekker, 1977, viii + 150 pp., $19.50.

Hirsch, Doris. *Indoor Plants—Comprehensive Care and Culture.* Radnor, Pa.: Chilton Book Co., 1977, xi + 225 pp., $15.00.

Hood, Kenneth. *Spice for Speakers, Sports and Squares.* Danville, Ill.: Interstate Printers and Publishers, 1976, xiv + 214 pp., $8.95.

Hood, Lamartine F., Edward K. Wardrip, G. N. Bollenback, eds. *Carbohydrates and Health.* Westport, Conn.: AVI Publishing Co., 1977, xi + 147 pp., price unknown.

Kuhnelt, Wilhelm. *Soil Biology, with Special Reference to the Animal Kingdom.* East Lansing: Michigan State University Press, 1976, 483 pp., $20.00.

Lebergott, Stanley. *Wealth and Want.* Princeton, N.J.: Princeton University Press, 1975, ix + 217 pp., $6.95.

Mann, Mary E. *The Fields of Dulditch.* Ipswich, England: Boydell Press, 1977, 318 pp., $7.50.

Martinez-Alier, Juan. *Haciendas, Plantations and Collective Farms—Agrarian Class Societies—Cuba and Peru.* Forest Grove, Ore.: Frank Cass and Co., 1977, viii + 185 pp., $19.50.

Mason, Bert, Alvin D. Sokolow, and Varden Fuller. *General Revenue Sharing and the Small Community: A Study of Five California Counties.* Davis: University of California, 1977, v + 98 pp., $4.00.

Maxwell, James A., and J. Richard Aronson. *Financing State and Local Governments.* 3rd ed. Washington, D.C.: Brookings Institution, 1977, xvi + 290 pp., $10.95, $4.95 paper.

Mitra, Ashok. *Terms of Trade and Class Relations—An Essay in Political Economy.* Totowa, N.J.: Frank Cass and Co., 1977, xi + 193 pp., $25.00.

Mundle, Sudipto. *District Planning in India.* New Delhi: Indian Institute of Public Administration, 1977, viii + 95 pp., $8.00.

Page, Talbot. *Conservation and Economic Efficiency: An Approach to Materials Policy.* Baltimore, Md.: Johns Hopkins University Press, 1977, xvii + 266 pp., $15.00, $4.95 paper.

Pine, Wilfred H. *Natural Resource Economics—Basic Principles.* Manhattan, Ks.: Wilfred H. Pine, 1977, 64 pp., $3.95 paper.

Shaffer, Harry G., ed. *Soviet Agriculture: An Assessment of Its Contributions to Economic Development.* New York: Praeger Publishers, 1977, xvi + 166 pp., price unknown.

Smith, Ora. *Potatoes: Production, Storing, Processing.* 2nd ed. Westport, Conn.: AVI Publishing Co., 1977, xi + 776 pp., $33.00.

Sultan, William J. *Modern Pastry Chef, Volume 1.* Westport, Conn.: AVI Publishing Co., 1977, viii + 360 pp., $28.00.

———. *Modern Pastry Chef, Volume 2.* Westport, Conn.: AVI Publishing Co., 1977, ix + 348 pp., $28.00.

Vagi, Ferenc. *Die Betriebliche Interessiertheit und der Mechanismus Ihrer Durchsetzung in den Staatsgutern.* Budapest, Hungary: Akademiai Kiado, 1977, 151 pp., $9.00.

Whitaker, John R., and Steven R. Tannenbaum. *Food Proteins.* Westport, Conn.: AVI Publishing Co., 1977, xi + 602 pp., price unknown.

Winger, Alan R. *Urban Economics: An Introduction.* Columbus, O.: Charles E. Merrill Publishing Co., 1977, viii + 374 pp., $14.50.

News

Announcements

Annual Meeting, 1978

The annual meeting of the American Agricultural Economics Association will be held jointly with the Canadian Agricultural Economics Society on 6–9 August on the campus of Virginia Polytechnic Institute and State University at Blacksburg. Professor Lee Chambliss is chairman of the local arrangements committee, and correspondence concerning the meeting should be directed to him. Program information and registration forms will be provided in the Presidential Newsletter and in mailings from the local arrangements committee.

Call for Contributed Papers

Contributed papers are invited for the 1978 AAEA meetings at Virginia Polytechnic Institute. Subject matter of the papers must be relevant to the discipline of agricultural economics.

Contributions by graduate and undergraduate students, as well as from experienced professionals, are solicited. Contributions are limited to AAEA members, except in special cases where this condition is expressly waived by the president. Papers should be forwarded by first-class mail and must be postmarked no later than 1 April 1978.

Each paper, including tables, footnotes, and references is not to exceed twelve double-spaced, typewritten pages. Each will be accompanied by a fifty-word abstract. Authors are urged to follow *Journal* guidelines in preparing manuscripts for review. Authors are limited to one contributed paper for which he or she is the sole or senior author; junior authors may appear on more than one paper.

Contributions will be reviewed by members of the Contributed Papers Committee of AAEA. In 1977, more than 40% of the papers contributed were selected for presentation at the annual meetings. Authors will be notified whether or not their papers have been accepted for presentation by 15 June 1978. Abstracts of contributed papers will be made available in advance of each session. These abstracts also will be printed in the 1978 Proceedings issue of the *Journal*.

Please accompany submissions with a brief biographical sketch which includes the author's name, title, institutional affiliation, degrees held, and a brief employment profile. Send four copies of each manuscript, a 50-word abstract, and the biographical sketch to Clark Edwards, chairman, Contributed Papers Committee, Economic Research Service, U.S. Department of Agriculture, Washington, D.C. 20250.

Symposia Plans Invited

Organized symposium sessions at the annual AAEA and CAES meetings in August will continue in their usual format as part of the annual meeting.

Each symposium should be organized around a single theme and sessions of one hour and forty-five minutes each may be presented. The organizer of each symposium will select the theme and run the symposium as he or she sees fit.

Because a limited number of symposia are held, they will be selected on a competitive basis. Those wishing to organize and present a symposium should send two copies of the complete plan of their session to Dr. R. J. Hildreth, president, AAEA, 1211 West 22nd Street, Oak Brook, Illinois 60521. Plans must be received by 3 April to be considered.

Each plan should consist of no more than two or three pages and should include the topic, a plan of organization and presentation, and the names and affiliations of participants along with a description of the role of each.

Abstracts of each symposium will be published in the *AJAE* and may be prepared after the symposia are selected.

Proceedings, Agricultural and Rural Data Workshop

The Agricultural and Rural Data Workshop, sponsored by the AAEA Economic Statistics Committee in conjunction with the Statistical Reporting Service, Economic Research Service, and the Agricultural Marketing Service of the U.S. Department of Agriculture, was held 4–6 May 1977, in Washington, D.C. The workshop brought together producers and users of data to develop suggestions and recommendations for use by agencies responsible for improving data and data series.

The workshop was conducted in two series: A, price reporting and the capacity of the food and fiber systems; and B, indicators of economic well-being of people engaged in farming and data for farm and rural employment.

Series A speakers and their topics were: "The Concepts of Price: Implications for Agriculture Data Collection and Use," James P. Houck; "Economic Structure, Price Discovery Mechanisms, and Informational Content of Agricultural Prices," Charles H. Riemenschneider; "Practical Problems in Price Reporting for Data Collection, Analysis, and Forecasting," Walter J. Armbruster and Richard J. Crom; "Perspectives on Capacity Concepts, Measures, and Uses for the Food and Fiber System," J. B. Penn; "Current Practices Related to Capacity and Capacity Utilization Measurement for

Food and Fiber Production—An Inventory," Eldon E. Weeks; and "A Critical Review of Alternative Measures of Capacity and Capacity Utilization," John B. Penson and W. E. Kibler.

Series B topics and speakers included: "A Short History of Agricultural Data Systems," David E. Brewster; "Income and Wealth Data for Indicating Well-being of People Engaged in Farming," Luther G. Tweeten, D. Lee Bawden, George Irwin, Thomas L. Browning, Thomas A. Carlin, and Peter M. Emerson; "Toward the Definition and Measurement of Farm Employment," James S. Holt, Robert D. Emerson, Conrad F. Fritsch, James R. Garrett, and Varden Fuller; and "Employment Data for Rural Development Research and Policy," Clark Edwards, Robert T. Coltrane, Conrad F. Fritsch, Ronald W. Holling, Sigurd R. Nilsen, and Jeanne M. O'Leary.

Milton C. Hallberg wrote the price reporting rapporteur's report, and Heinz Spielmann, wrote the series B report. Single copies of the Series A proceedings are available from W. E. Kibler, administrator, Statistical Reporting Service, USDA, Washington, D.C. 20250 (phone 202-447-2707); and Series B, from U.S. Department of Agriculture, Economic Research Service, Information Division, Publications Services, Washington, D.C. 20250 (phone 202-447-7255).

Conference on Irrigation, Drainage, Water Resources

A specialty conference with the theme, "Legal, Institutional, and Social Aspects of Irrigation and Drainage and Water Resources Planning and Management," jointly sponsored by the Irrigation and Drainage Division and the Water Resources Planning and Management Division of the American Society of Civil Engineers will be held at Blacksburg, Virginia, on the Virginia Polytechnic Institute and State University campus on 26–28 July 1978. Interested professionals from disciplines other than engineering are invited.

Further information about the conference may be obtained by writing Dr. William Walker, Director, Water Resources Research Center, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061.

Personnel

Agricultural Development Council

Appointments: Hans B. Binswanger, formerly with the Research Unit, ICRISAT, and council associate in India, is at the Department of Economics, Yale University, for one year. **C. Geoffrey Swenson,** former council associate at Bogor, Indonesia, is at the Department of Agricultural Economics, Cornell University, for one year.

University of Arizona

Appointments: Dennis Cory is an assistant professor and assistant research scientist; **Louise Arthur** and **Eric Oswald,** formerly with ERS, USDA, are adjunct assistant professors.
Leave: Roger Fox is on sabbatical at the International Food Policy Research Institute, Washington, D.C.
Honor: Jimmye Hillman has been named by the FAO director general as North American representative to the first FAO expert consultation on agriculture: "Towards 2000."

University of Arkansas

Appointment: Ralph D. May is associate editor of the *Southern Journal of Agricultural Economics,* 1978–80.

Colorado State University

Appointments: A. H. Gilbert, University of Vermont, is a visiting associate professor; **R. A. Young,** just returned from Lincoln College, Canterbury, New Zealand, where he was Fulbright-Hays Senior Research Fellow in water resource planning, is director of graduate programs and assistant chairman of the Economics Department.
Return: D. W. Seckler is back from a three-month Ford Foundation assignment in India.

Cornell University

Appointments: A. Kandsawamy, associate professor at Tamil Nadu Agricultural University in India, was a visiting fellow from 1 Sep. through 31 Dec. 1977; **Gordon King,** University of California, Davis, was a visiting fellow during the same period. **John M. Mugar,** chairman, Star Market Company, was Julius Hendel Visiting Lecturer in Food Distribution for the fall semester; **Jan Sweeney,** University of British Columbia, is a visiting assistant professor.
Leaves: Eddy L. LaDue, associate professor, is on leave with NEAD, ERS, USDA, until August; **Robert J. Kalter,** professor of resource economics, is on leave with the Department of Energy, Washington, D.C.
Resignations: Doyle A. Eiler, assistant professor, is with the Food Marketing Institute, Washington, D.C.; **John Mellor,** professor, is director of the International Food Research Institute, Washington, D.C.
Honors: Kenneth L. Robinson has been elected by the Cornell University Board of Trustees, Liberty Hyde Bailey Professor of Agricultural Economics; **Robert S. Smith,** professor of farm finance, has been named the first William I. Meyers Professor in Agricultural Finance.

University of Florida

Return: Max R. Langham has returned from a two-year assignment with ADC in Singapore and the University of the Philippines, Los Banos.

University of Georgia

Appointment: James E. Epperson, Ph.D. Mississippi State University, is an assistant professor, stationed in Griffin.

University of Illinois

Appointment: David A. Myers is an assistant professor.
Leaves of absence: A. G. Harms will go to Peru for two years; **M. M. Wagner** leaves for Thailand in June.
Return: E. D. Kellogg has returned from a two-year Ford Foundation assignment in Thailand.

Kansas State University

Appointments: Delton C. Gerloff, M.S. Oklahoma State University, is area extension economist, Farm Management Association, stationed in Hiawatha; **Van Harrold** is an area extension economist, Farm Management Association, located in

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ADC: Agricultural Development Council; ERS: Economic Research Service; FAO: Food and Agriculture Organization; FCA: Farm Credit Administration; NEAD: National Economics Analysis Division of ERS.

Hutchinson; **Fred V. Hess,** formerly dean, College of Agriculture, is team leader, KSU-AID-GRP Philippine Project, and will be stationed in Manila for about two years.
Retirement: Hobert W. Frederick, area extension economist, Farm Management Association.

University of Maryland

Leave: John W. Wysong, professor of agricultural and resource economics, is on sabbatical leave through June 1978, in Australia and New Zealand.

Michigan State University

Leave: Derek Byerlee has returned from two years with the Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT).
Return: Darrell Flenup has returned from two years with the MSU-Brazil Project.
Resignation: Kelly Harrison, is general sales manager, Foreign Agricultural Service, USDA.

University of Minnesota

Appointments: Vernon W. Ruttan, former president, ADC, is a professor of agricultural and applied economics; **Tippanna K. Meti,** head of the Department of Economics, Karnatak University, Dharwar, India, was a visiting honorary fellow Sep.-Dec. 1977; **Chellappa Suyambulingom,** Tamil Hadu Agricultural University, Coimbatore, India, is visiting associate professor through March.

Mississippi State University

Appointment: Lynn L. Reinschmiedt, formerly with the Department of Agriculture and Food Economics, University of Delaware, is assistant professor and assistant agricultural economist.

University of Missouri

Appointments: Melvin G. Blase is director of international programs and coordinator of Title XII programs; **Robert M. Finley** has been appointed to the Governor's Council on Agriculture.
Leave: David E. Moser will serve the Missouri Public Service Commission as senior transportation economist and chief coordinator of an evaluation of the Commission's transportation regulatory functions.
Returns: Donald D. Osburn is back from two years at FCA, Washington, D.C.; **C. Brice Ratchford** has returned from a year at Kansas State University.
Retirement: Stephen F. Whitted, former professor, after 26 years.

New Mexico State University-Las Cruces

Appointments: Martin J. Blake, Ph.D. University of Missouri, is an assistant professor of agricultural marketing; **Joel A. Diemer,** Ph.D. Colorado State University, is an assistant professor of land resource economics; and **Wilmer M. Harper,** Ph.D. Oklahoma State University, is an assistant professor of economic development and agricultural policy.
Leaves: William N. Capener is on academic leave with Texas A&M University through June; **Milton M. Snodgrass** is on a two-year leave with the Rockefeller Foundation, Department of Agricultural Economics, University of Ibadan, Nigeria.

Ohio State University

Appointment: Yuzuru Kato, University of Tokyo, is a visiting professor through June 1978.

Oklahoma State University

Appointments: James E. Osburn, formerly of Texas Tech, Lubbock, is head of the Department of Agricultural Economics; **Alan Baquet,** formerly at Michigan State University, is an assistant professor.

Oregon State University

Appointment: Michael V. Martin, Ph.D. University of Minnesota, is an assistant professor of agricultural marketing.

Purdue University

Appointments: Timothy G. Baker, Ph.D. Michigan State University, is an assistant professor; and **David C. Lyons,** M.S. Purdue University, is a temporary instructor.
Leave: Henry Courtenay, assistant professor, is on sabbatical leave during 1978, at Queens University, Northern Ireland.
Return: Otto C. Doering, associate professor, returned from leave in September 1977. He was with ERS, USDA, in Washington, D.C.
Honors: Jan Armstrong, professor, received the Senior Award presented by the Purdue University Cooperative Extension Specialist Association at the extension workers banquet, 18 Oct. 1977. **W. David Downey,** professor, will serve a two-year term on the advisory council of the American Potash and Phosphate Institute. **Manuel Villa Issa,** Ph.D. Purdue University, 1976, received an honorable mention award for his dissertation, "The Effect of the Labor Market on the Adoption of New

Production Technology in a Rural Development Project: The Case of Plan Puebla, Mexico." The award was presented at a ceremony by the president of Mexico.

Stanford University

Appointments: Timothy Josling is a professor; **Reynaldo Martorell** is an associate professor; **Scott Pearson** is associate director of Food Research Institute; **David J. S. Rutledge,** Macquaries University, Sydney, Australia, is visiting associate professor; and **J. Dirck Stryker,** Fletcher School of Law and Diplomacy, Tufts University, is visiting associate professor.
Leaves: Roger Gray and **Dennis Chinn** are on leave.
Return: Tetteh A. Kofi has returned from a year's leave.

University of Tennessee

Appointments: Morgan Gray, formerly with the Tennessee Department of Health, is a research associate; **B. H. Pentecost,** former professor of agricultural law, is assistant vice-president for agriculture.

Virginia Polytechnic Institute and State University

Appointments: Marion Brokaw, M.S. University of Delaware; **David Hull,** M.S. Rutgers University; **Carl Mabbs-Zeno,** M.S. University of Georgia; and **David Orden,** M.S. Virginia Polytechnic Institute and State University, are research associates.
Leave: Leonard A. Shabman is with the Water Resources Council, Washington, D.C.
Resignation: Ewen M. Wilson, is director of economics and statistics, American Meat Institute, Arlington,Virginia.

University of Wisconsin

Honor: John D. Strasma received a "Citation of the Assembly" for his outstanding service in connection with developing the new Wisconsin Mining Tax Law.

University of Wyoming

Appointment: Larry J. Held, Ph.D. University of Nebraska, is an assistant professor.
Retirement: D. M. Stevens is a professor emeritus after 27 years of service.

Other Appointments

Rodney Baker, M.S. University of Arkansas, is with the Arkansas Farm Bureau, Community Division—Soybeans and Rice, Little Rock.
Michael Belongia, M.S. Virginia Polytechnic Institute and State University, is with ERS, USDA, Washington, D.C.
Marshall Burkes succeeds **Kurt B. Eckrich** as director, finance and management department, International Bank for Reconstruction and Development.
Yang Boo Choe, Ph.D. University of Missouri, is an agricultural economist at the National Agricultural Economics Research Institute, Seoul, Korea.
Thomas Edgar, M.S. Virginia Polytechnic Institute and State University, is manager, Virginia Agribusiness Management Association, Lynchburg.
Gerald Ehlmann, M.S. University of Missouri, is a computer programmer II, Department of Agricultural Economics, University of Missouri-Columbia.
Bashir El-Wifati, Ph.D. University of Missouri, is chairman, Department of Agricultural Economics, University of Libya, Tripoli.
Patricio Espinosa, M.S. University of Missouri, is an economist with INIAP, National Agricultural Research Institute of Quito, Ecuador, and teaches at Central University.
Stephen L. Haynes, M.S. Virginia Polytechnic Institute and State University, is a research associate, Louisiana State University.
Kwang Hi Im, M.S. Oregon State University, is principal economist, Alaska Department of Fish and Game.
C. Mac Swortzel, M.S. Virginia Polytechnic Institute and State University, is with the Farm Credit System, Staunton, Virginia.
Lionel Williamson, Ph.D. University of Missouri, is associate professor and extension specialist at North Carolina Agricultural and Technical State University, Greensboro.

Obituaries

R. H. Allen

R. H. "Til" Allen, a pioneer in foreign economic development, died of a stroke in Washington, D.C., 23 September 1977.

Allen received a B.S. degree from the University of Maine in 1929, a M.S. from the University of Connecticut in 1931, and a Ph.D. from the University of California, Berkeley in 1934. All three degrees were in agricultural economics. He worked with the Resettlement Administration 1934–37, Harvard University in 1937 and 1938, and USDA 1938–39. He then joined the faculty of the University of Kentucky, where he remained until 1942. He returned to USDA and the War Food Administration. In 1944, he enlisted as a lieutenant in the U.S. Navy and served with the OSS in England and France, then with SHAEF in Germany. After the war, he worked with UNRRA, Washington, D.C., then FAO. From 1948–52, he was with the Marshall Plan office in Paris, heading its food and agriculture division 1950–52.

Always an agriculturalist at heart, Allen bought and operated a farm in Carlisle, Pennsylvania 1953–55 and 1958–61, taking time out 1955–57 to serve as economic advisor to the Ministry of Agriculture, Tehran, Iran. In 1961 he joined Robert R. Nathan Associates, a Washington based consulting firm. While with them he carried out long-term assignments in Afghanistan and Ghana. He was Director of International Operations when he retired in 1971. Following his retirement from Nathan, he went with the World Bank on assignments to Malaysia and Korea. Other short-term assignments and travels took him, at one time or another, to most of the countries around the globe.

Those who knew Allen will remember his keen intellect in applying economic theory in a pragmatic manner. He was a gentle and humane man, and there is no doubt about his outstanding contributions to making this world a better place to live.

He is survived by his widow, Betty, who has set up the R. H. Allen Scholarship Fund at the Alumni Center, University of Maine, Orono, Maine 04473.

Morris Evans

Morris Evans, professor emeritus, New Mexico State University, Las Cruces, died on 6 November 1976, at the age of 85 years.

John Wayne Nixon

John Wayne Nixon, assistant professor of agricultural economics, University of Georgia, Athens, died 11 August 1977 at the age of 40.

Nixon was born near Mt. Airy, North Carolina, and received his undergraduate education at Berea College in Kentucky. He was awarded the M.S. degree in agricultural economics by North Carolina State University in 1962 and the Ph.D. degree from Michigan State University in 1969. He joined the faculty at the University of Georgia in 1968 where he remained until his death.

He was exceptionally dedicated to his profession, serving as editor of the *Southern Journal of Agricultural Economics* from 1975 until his death and as a member of the editorial board 1973–75. Perhaps his greatest professional contribution was promotion of the *Southern Journal* to a position of national recognition among professional journals.

He served the American Agricultural Economics Association as a member of the Student Affairs Committee and as vice-chairman of the Student Section debate competition 1971–73. Nixon was a dedicated teacher and counselor of students in and outside the classroom. He was named by students as the outstanding teacher in agricultural economics at Georgia in 1973 and 1977.

To those who knew Nixon best, he will be remembered as a truly Christian gentleman, devoted to his family and to his church. He founded a Sunday school class which is now named in his honor and was chairman of the board of deacons. He and his family found great strength in their Christian devotion throughout John's illness.

He is survived by his widow Marilyn, son David, and daughter Melanie.

David Woodrow Parvin, Sr.

David Woodrow Parvin, Sr., professor emeritus and former head of the Department of Agricultural Economics, Mississippi State University, died 23 September 1977 at the age of 60. Parvin was born in Biggersville, Mississippi, in 1917. He received a B.S. in 1938 and M.S. in 1941 from Mississippi State University and his Ph.D. from the University of Virginia in 1944.

Except for the time spent in graduate school at the University of Virginia and in the U.S. Army, he served Mississippi State University 1938–72. He was head of the department from 1956 until his retirement.

As a young faculty member, Parvin was a productive researcher and a dedicated teacher of farm management. His sincere interest in students, both undergraduate and graduate, and his counsel and encouragement, as a professor and later as an administrator, inspired and motivated them to achieve excellence in their studies and in their professional lives. His genuine concern for young people led him to devote considerable time to the organization and

operation of summer youth activities in the local community. As a department head, his wisdom and counsel were valued highly by both his associates and his students.

Parvin was a member of a number of professional associations, of Gamma Sigma Delta, and was a longtime active member of the MSU Alumni Association, serving as membership chairman in 1962, when a record for new membership was established. He was honored by the alumni association for his service to it and the University following his retirement.

He is survived by his wife, Bernice, and three sons, David, Jr., Steve, and Gary.

Tyrus R. Timm

Tyrus R. Timm, professor emeritus, Texas A&M University, College Station, died 4 September 1977. He was born 27 August 1912, at Hallettsville, Texas. He received his bachelor's degree in marketing and finance in 1934 and his master's degree in agricultural economics in 1936 from Texas A&M University. He also received a master's degree and Ph.D. in public administration in 1947 and 1949, respectively, from Harvard University.

Timm began his professional career as agricultural economist at New Mexico State University, Las Cruces, in 1936. He served as farm management specialist with the Texas Agricultural Service 1938–44; agricultural economist, Office of Price Administration, Washington, D.C., 1944–45; administrative assistant, extension service, Texas A&M, 1946–49; professor of agricultural economics and extension economist, Texas A&M, 1949–53; and as head of the Department of Agricultural Economics and Rural Sociology, Texas A&M University, 1953–73. He also served part time as full professor and research economist until he retired as professor emeritus in 1975. The European Common Market was his central research interest during the last two decades.

Among the many honors and awards Timm received were the 1977 Distinguished Service Award from the Texas Federation of Cooperatives, the Houston Bank for Cooperatives, and the Texas Cooperative Ginning Association; a special award from the Texas Farm Bureau Federation for meritorious service to Texas agriculture; the Texas Academy of Honor Award in Agricultural Credit from the Federal Land Bank, Federal Intermediate Credit Bank, and the Bank for Cooperatives of Houston; and citation for distinguished service to the Texas A&M College of Agriculture by the Texas House of Representatives in 1976. He was recognized in 1975 by the National Public Policy Education Conference as the only land grant university representative in the nation to have served continuously on the national committee during the NPPEC's 25-year existence.

Texas A&M President Jarvis E. Miller said that "Ty Timm exemplified all the qualities that make a man great—humility, dedication, loyalty, integrity, concern for others. Quiet, unassuming, he always knew how to get things done. He has left a lasting mark on this university, this state, and this nation." The family has requested that any memorials be made to the Tyrus R. Timm Fellowship Fund at Texas A&M University.

Richard G. Wheeler

Richard G. Wheeler died on 30 September 1977 at Winsted, Connecticut. He was sixty years old. His professional work on five continents ranged from economic planning with individual farmers to planning agrarian reform and economic development in such nations as Colombia, Brazil, the Federation of Malaysia, Afghanistan, and Liberia.

At his death, Wheeler was senior associate-economic consultant with Robert R. Nathan Associates, Washington, D.C. He had been a faculty member at the University of Connecticut, where he received B.S. and M.S. degrees, and a research fellow and project leader at Harvard University, where he earned his M.A. and Ph.D. degrees. He also served as a faculty member at Michigan State University, consultant to the Department of Agriculture for Scotland, and held a variety of domestic and overseas posts with U.S. Department of Agriculture and the Agency for International Development.

Characteristic of his broad interests, Wheeler's most recent book, *Barkhamsted Heritage: Culture and Industry in a Rural Connecticut Town,* conceived as a bicentennial project for the community which he considered his home for many years, and for its historical society, of which he was a member.

His professional memberships included the American Agricultural Economics Association, Northeastern Agricultural Economics Council, International Association of Agricultural Economists, and Sociedade Brasileira de Economistas Rurais. Biographies appear in *American Men of Science, Who's Who in the East,* and *Two Thousand Men of Achievement.*

Born in Wethersfield, Connecticut, on 9 July 1917, the son of the Rev. Mr. Warren Eli and Kate Adams Wheeler, Wheeler is survived by his wife, Helen Munson Wheeler, three sons and two daughters, and two granddaughters.

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The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

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Volume 60 Number 2

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In this issue: Proceedings papers from the 1977 winter meeting

AAEA Annual Meeting
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia
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American Journal of Agricultural Economics

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Oligopoly Pricing in the World Wheat Market

Chris M. Alaouze, A. S. Watson, and N. H. Sturgess

When the residual demand curve for wheat facing the United States and Canada shifts to the left, or when the exportable surplus of Australia is large, market-shares of these duopolists are reduced. Such circumstances lead to the formation of a market-share triopoly with Australia. The evidence for this proposition is examined and a model of triopoly pricing in the world wheat market is presented. If major exporters continue to be concerned with relative market-shares, the triopoly will reform, stocks will accumulate, and lower prices will prevail; however, prices will be more variable, and possibly higher, than before 1972/73.

Key Words: demand, oligopoly model, supply, wheat stocks, world wheat pricing.

Introduction

Before 1972, the world wheat market was characterized by a long period of price stability and large inventories which were held by the major exporters, the United States and Canada, and after 1968/69, by Australia. Price formation in the world wheat market has been analyzed in an oligopolistic framework by McCalla and Taplin.[1] Their models are based on a cooperative duopoly between the United States and Canada, with other producers either following the price set by the duopolists (with a discount for quality) or pricing sufficiently below to clear their current stocks.

Both models describe pricing along the residual demand curve facing the duopolists, and the way in which North American exports are shared between them. However, both authors recognize that the maintenance of some minimum share of the total export market is essential for the stability of the duopoly.

The increase in Australian wheat production that occurred during the late fifties and sixties coupled with the Australian policy of pricing to sell the whole crop can be seen as a destabilizing influence on the duopoly, especially in years of high world production and contracting export markets.

These factors were responsible for the price wars that occurred in 1965/66 and 1968/69. This paper argues that a direct result of the price wars (particularly 1968/69) was the emergence of a triopoly involving the United States, Canada, and Australia.

Since 1972, the world wheat market has been characterized by high, unstable prices and low carryover stocks, indicating that the market has been operating essentially competitively. At time of writing, prices have begun to fall and stocks are increasing, indicating that a return to some form of stable, oligopolistic market may be occurring.

This paper is organized as follows. In the first section, the two duopoly models are reviewed. The second section discusses the evidence for the formation of the triopoly, and the third section develops a model of triopoly pricing. Price determination within the model, the future of the triopoly and its implications for future wheat prices are discussed in the final two sections.

Models of Duopoly Pricing

The models developed by McCalla and Taplin are concerned with pricing along the residual

Chris M. Alaouze is a research assistant at the University of Wisconsin, formerly at the University of Melbourne, Australia; A. S. Watson and N. H. Sturgess are senior lecturers in agricultural economics at the University of Melbourne.

The authors acknowledge the helpful comments of the anonymous reviewers.

[1] By convention, the world wheat market refers only to wheat sold under normal commercial terms. This excludes barter, food aid, transactions under PL 480 and sales made for local currencies. In this paper, time periods describe the crop year of the country under discussion.

demand curve facing the duopolists. This is obtained by subtracting the supply curves of competing exporters and producers from the world demand curve. This construction involves an assumption that wheat is a homogeneous commodity. Both McCalla and Taplin argue, and we accept, that this assumption is plausible because wheats of different grades are close substitutes. The elasticity of substitution between soft and hard wheats is high enough for the pricing policies of the minor exporters to erode the total market shares of one or more of the duopolists. For example, price reductions by Australia and Argentina in 1964/65 were responsible for the low total market share of the United States in that season. U.S. price reductions (aimed specifically at Australian wheat exports) in 1965/66 were effective in restoring the total market share of the United States (Taplin, pp. 113–19). The fact that market shares are price sensitive, given the importance that the duopolists place on their shares of the total export market, indicates that the homogeneity assumption is acceptable for analyzing the world wheat oligopoly.

McCalla analyzed the market as a duopoly rather than a triopoly because only the United States and Canada possessed the storage facilities necessary to hold the stocks required to exert market power. McCalla defined market power as the willingness and ability to hold stocks.[2]

McCalla also assumed the following points: (*a*) There is a price leadership, and Canada is the leader. (*b*) Each seller is aware of how the other will react to his own actions. (*c*) There is a maximum price above which the second seller will not follow the leader and a set of prices and quantities which define the second seller's minimum market share. In this band, the second seller will accept prices as determined by the first and sell whatever quantity remains. (*d*) The leader has some minimum quantity he must sell and some minimum price below which he would rather hold than sell. (*e*) Both sellers wish to maximize exports.

These assumptions define a set of prices and quantities in which a solution is possible. This set (or zone of cooperation) expands and contracts with movements of the residual demand curve, because the set is bounded in part by the market-share curve of the second seller, which position depends on the position of the residual demand curve. The zone of cooperation is also bounded by the minimum quantity which the price leader must sell, but this quantity is independent of the residual demand curve. In McCalla's model, severe contraction in demand facing the duopolists can lead to a breakdown of the duopoly. An increase in the exportable surplus of one of the fringe suppliers can therefore be seen as a destabilizing influence on the duopoly (other things being equal) as this reduces the area of cooperation.

Taplin was critical of McCalla's assumption that the duopolists seek to maximize exports subject to their constraints. He pointed out that because the incomes of Canadian wheat farmers are determined largely by export prices, producers' returns must be a principal concern of Canadian export policy (also see Bieri and Schmitz).

Taplin argued that in the case of the United States, farm incomes are important, but they had little relationship to export revenue. United States export policy was regarded as being much more flexible than that of Canada because of the role of the United States as a world power.

In this context, Taplin suggested that Canada generally acted as a pure monopolist, setting price to maximize revenue, with the United States following. The two countries therefore tended to maximize revenue even though the United States has other objectives.

Taplin's model was based on a combination of the market share and kinked demand curve solution to the stable oligopoly problem (Henderson and Quandt, pp. 183–86). He based the assumption of constant market shares of the residual market on the stability exhibited by these shares in the period 1958/59 to 1963/64, and statements by officials of the U. S. Department of Agriculture and the U. S. government, in 1967 and 1968 respectively, that maintenance of market shares is an important facet of U. S. wheat policy (Taplin, pp. 33–55).

The main features of this model are shown in figure 1. The world demand curve for wheat exports is *DD*, the supply curve of competing exporters is *SS*, and the residual demand curve facing the duopolists is *D'D'*. The two shares

[2] Freebairn criticized McCalla's assumptions that wheat is homogeneous and that only the United States and Canada possess market power. In our view, it is doubtful that Australia possessed much market power in the form of stocks during most of the sixties, because the Australian Wheat Board (which sells and stores all wheat grown) was barely able to increase its storage capacity enough to cope with the increasing production during the period. (See Table 1).

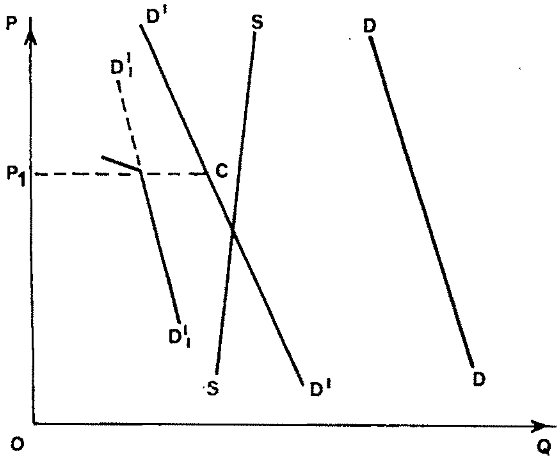

Figure 1. Taplin's model of duopoly pricing

of the residual market are defined by the market-share curve, $D_1'D_1'$. This is drawn assuming each duopolist has a constant share of the residual market. The price leader, Canada, has the share to the left of $D_1'D_1'$, and the United States, the share to the right. The assumption of constant market shares implies that if one duopolist changes his price, the other will make an equivalent change in price. The kink is introduced by assuming that there exists some price, P_1, above which the second duopolist will not follow the first. The upper portion of the kinked demand curve is assumed to have some slope, because the wheats of the two sellers are imperfect substitutes and there is imperfect knowledge or inertia among the buyers.[3] Taplin assumed that the price leader, Canada, adopts a pricing strategy to maximize revenue. Consequently, the market price, P_1, is set at or near, the point of unitary elasticity, C, on the residual demand curve.

The assumption of constant market shares implies that the duopolists hold surplus stocks. Canada, in seeking a profit maximizing strategy, must consider factors such as the trade-off between the discounted expected gains (or losses) associated with storage and the revenue associated with setting price above (or below) the point of unitary elasticity. In the remainder of the text, we assume that the price leader always attempts to maximize its return from current exports.

The kinked demand curve approach is usually used to explain the stability of prices; however, it is known that prices are not constant. This instability is due to shifts in the residual demand curve which result from either shifts in the world demand curve for wheat exports and/or shifts in the supply curve of competing exporters.

Taplin explains price changes in his model as follows. When the residual demand shifts to the right, the price leader (Canada) can either keep the price unchanged or increase it. However, if the second duopolist (the United States) does not follow, the first duopolist risks losing its market share. In practice this problem is overcome by daily revision of the selling price. If the United States does not follow Canada, then Canada revises the price downwards within one or two days and the status quo is maintained.

A shift to the left of the residual demand curve can result in price reductions. In this case, the second duopolist will always match the price decrease. This is a basic assumption underlying the kinked demand curve analysis. In Taplin's analysis, the rationale for this is the requirement that market shares remain constant. The new price is set at the point of unitary elasticity on the new residual demand curve facing the duopolists, and the kink is reestablished on the market-share curve (corresponding to the new residual demand curve) at the revenue-maximizing price.

The fact that price wars have occurred establishes the tenuous nature of the United States-Canadian duopoly. Taplin (p. 66) interpreted the price wars as showing a limitation of the kinked demand-curve approach to pricing on the world wheat market.

We interpret the price wars as indicating an unstable duopoly situation because of the actual or potential erosion of one or both of the market shares of the duopolists by other exporters. This is similar to the "shakedown period" of price instability which often accompanies the formation of some stable industrial oligopolies (Baran and Sweezy, p. 63). Price stability is achieved when oligopoly pricing guarantees satisfactory shares of the export market. The kinked demand curve is a useful economic model which can be used to explain this stability.

Evidence for the Formation of a Triopoly

Table 1 implies that after the 1965/66 price war, Australia no longer pursued a policy of

[3] This introduces a minor contradiction. By constructing the residual demand curve by subtraction, Taplin implicitly assumed that wheat is homogeneous. To the extent that this assumption is not true, introducing slope to the upper portion of the kink adds realism to the analysis.

Table 1. Australian Wheat Production, Storage Capacity, and Carryover Statistics: seasons 1956/57 to 1974/75

Season[a]	Bulk Storage Capacity[e] (tonnes)	Outward Carryover[b]	Deliveries (tonnes)	Opening Stocks (tonnes)
1956/57	6,630,566	1,127,000	3,269,408	—
1957/58	6,736,391	445,000	2,213,322	3,340,322
1958/59	6,823,489	1,776,000	5,427,253	5,872,253
1959/60	7,117,420	1,665,000	4,880,815	6,656,815
1960/61	7,544,420	669,000	6,884,195	8,549,195[d]
1961/62	7,798,231	487,000	6,104,175	6,773,175
1962/63	8,289,826	638,000	7,776,081	8,263,081
1963/64	8,920,468	558,000	8,377,948	9,015,948[d]
1964/65	9,910,751	665,000	9,430,486	9,988,486[d]
1965/66	10,968,427	452,000	6,379,226	7,044,226
1966/67	11,789,848	2,188,000	11,954,061[c]	12,406,061[d]
1967/68	12,686,418	1,409,000	6,732,308[f]	8,920,308
1968/69	13,946,734	7,258,000	14,033,062	15,442,062[d]
1969/70	18,832,635	7,217,000	9,754,838	17,012,838
1970/71	19,771,448	3,400,000	6,935,650	14,152,650
1971/72	19,438,160	1,448,000	7,665,954	11,065,954
1972/73	20,275,753	478,000	5,437,537	6,885,537
1973/74	20,524,448	1,882,000	11,199,907	11,597,907
1974/75	20,192,662	1,658,000	10,703,822	12,585,822

Source: Australian Wheat Board, *Annual Reports* 1955/56 to 1974/75.
[a] 1 December to 30 November.
[b] As at 30 November.
[c] Deliveries exceed storage capacity.
[d] Total stocks exceed storage capacity.
[e] As at 1 December. Includes capacity of flour mills.
[f] This low level of production was due to the drought that affected the Australian wheat-sheep zones in 1967/68.

pricing to sell its exportable surplus. From 1966/67 to 1971/72, Australian carryover stocks ranged from 1.4 to 7.3 million tonnes compared with minimum transactions stocks of about half a million tonnes for the preceding six years.

In addition, the 5.8 million-tonne increase in stocks in the 1968/69 season and the 4.9 million-tonne increase in storage capacity in the 1969/70 season indicate that Australia was prepared to exercise considerable restraint in its wheat marketing after the 1968/69 season. Because of the importance of these events to our argument, we shall discuss the 1968/69 season in some detail. The two major factors responsible for the price war of 1968/69 were the contraction of the export market due to high production in importing countries and the record 14 million tonne Australian wheat crop.

These events coincided with the implementation of the new International Grains Arrangement (IGA) which came into operation in July 1968. In the new IGA, twelve grades of wheat were introduced on which the minimum pricing provisions were based; these replaced the single grade which existed under the preceding International Wheat Agreement (IWA). In addition, the prices of the new grades were increased by 19¢ per bushel relative to their prices under the old IWA.

Australian wheat, however, was still sold officially as one grade, faq (fair average quality). When the United States and Canada discovered that Australia was selling hard wheat as faq and, therefore, undercutting their export prices, two additional grades of Australian wheat were introduced at their insistence in September 1968 (Connors, pp. 61–63). Despite this action, low world demand and high production in exporting countries emasculated the pricing provisions of the IGA.

Stigler (pp. 42–44) has argued persuasively that attempts at secret price cutting by participating parties is a likely feature of collusive market-sharing oligopolies (or cartels). However, he also shows that the probability of detection is high. In the context of Stigler's analysis, the pricing provisions of the IGA can be viewed as part of the mechanism of formalizing and policing oligopoly pricing on the world wheat market. McCalla (p. 725) had concluded from his analysis that the IWA had continued to exist because it was consistent with the goals of the major participants. The

fact the the IGA was ignored in 1968/69 is further evidence that the old duopoly was unstable in this season.

In the 1968/69 season, Australia had about 13.8 million tonnes available for export. Of this, only 6.6 million tonnes was exported, leaving a carryover of 7.2 million tonnes, nearly three times the previous highest postwar carryover of 2.5 million tonnes in 1954/55. Two reasons can be advanced to explain this carryover. First, it is likely that any attempt by the Australian Wheat Board (AWB) to export the full surplus in the depressed marketing conditions that then prevailed would almost certainly have exacerbated the existing price war. (The fact that Australia showed marketing restraint is indicative that the elasticity of the residual demand curve facing the United States, Canada, and Australia was inelastic at lower prices. We shall pursue this point further in the following section.) Second, it is likely that the AWB was under government pressure because the export price was already below the price guarantee for 200 million bushels under the wheat stabilization scheme, and any further reductions in world wheat prices would increase treasury payments under the scheme.

In July 1969, a special meeting of the exporting members of the IGA was held in Washington, largely to discuss a proposal by the United States that the pricing provisions of the IGA be suspended for six months. In a subsequent press statement, the AWB clearly indicated that a prime concern of the meeting was market shares, and that Australia would cooperate in maintaining the market shares of the United States and Canada. The relevant parts of the AWB press statement read as follows:

> Through its marketing competency, its shipping arrangements and the favourable pricing provisions of the IGA, the Board had increased Australia's share of a contracting wheat market. On the other hand the minimum prices of the IGA were working unfavourably for other exporters, notably the United States and Canada. . . . It was because of these long-standing difficulties, Dr. Callaghan said, that the Washington meeting recognised that some adjustments would be necessary in order to restore to some individual exporters a share of the commercial market which they could reasonably have anticipated under normal trading conditions. . . . Australia had indicated that it was ready to make a contribution to assist other exporters to regain an equitable share of the market . . . (AWB 1969).

This is clear evidence of collusion between the United States, Canada, and Australia, and suggests that Australia was willing to form a market-share triopoly with the United States and Canada.

The U. S. proposal to drop the pricing provisions can be regarded as a direct threat of intensifying the price war. Had Australia exported all of its surplus wheat in the smaller export market of 1968/69, any attempt to maintain prices would have required a reduction in the total market shares of the United States and Canada.

In 1970, there was little improvement in the world marketing situation, and despite the introduction of Australian wheat quotas for the 1969/70 season, the carryover remained almost unchanged. The quota for the 1969/70 season was 10.3 million tonnes. In order to accept delivery of this quota while 7.26 million tonnes of wheat from the 1968/69 season was stored in the silo system, the capacity of the grain-handling system was increased by 4.9 million tonnes in less than twelve months (see table 1).

These events lead us to conclude that Australia was participating in a market-share triopoly with the United States and Canada in these two years. This had been envisaged by McCalla: "Rapid increases in Australian wheat acreage, coupled with the declining stock position of the United States and even more of Canada, may bring about a change in the power structure. Two possibilities stand out. First, the formation of a triopoly, with Australia moving up from the fringe, could occur. Second, and more likely, the United States could emerge as the dominant wheat power" (p. 726).

One interpretation of the preceding discussion is that the United States and Canada view their shares of the total export market in terms of their shares of the residual market facing their exports and those of Australia. The export shares of these three producers are presented in table 2. The importance of market shares in the wheat triopoly is evident when these are considered in the context of total potential exports in each season; for this reason, the carryover stocks of the major exporters are presented in table 3.

The stability of market shares from 1968/69 to 1971/72, given the large carryover stocks held by each of the major exporters, provides support for the hypothesis of a market-share oligopoly between Australia and the North American exporters during this period. In

Table 2. Shares of the Residual Market Facing the United States, Canada, and Australia

Season[a]	United States	Canada	Australia
1962/63	21.47	51.29	27.24
1963/64	28.90	46.85	24.26
1964/65	20.11	51.77	28.12
1965/66	28.24	51.89	19.87
1966/67	30.39	47.33	22.28
1967/68	32.53	37.74	29.73
1968/69	31.69	42.24	26.07
1969/70	30.42	38.54	31.05
1970/71	33.07	35.98	30.95
1971/72	27.84	42.35	28.08
1972/73	54.75	33.38	11.87
1973/74	62.25	25.69	12.06
1974/75[b]	55.04	26.13	18.83

Sources: U.S. Department of Agriculture, *Wheat Situation* (various issues); International Wheat Council, *World Wheat Statistics* (various issues).
[a] July to June basis.
[b] Provisional.
Note: For the purposes of this table, U.S. exports were defined as wheat sold for cash and Commodity Credit Corporation credit. U.S. wheat exports for the 1971/72 seasons and after do not include flour exports, as these data are not available separately from total wheat exports (including concessional) after the 1970/71 season. The effect of this omission on the table is probably small, as flour exports (allocated to the two categories above) are generally trivial. For example, in 1970/71, these flour exports were only 2.5% of U.S. wheat sales and less than 1% of sales of the United States, Canada, and Australia in total.

1972/73, the market shares of the three exporters were vastly different from the previous five years. The carryover stocks of the oligopolists were depleted in meeting the episodic demands caused by crop failures in the USSR and some Asian countries. This illustrates the role of surplus carryover stocks in the maintenance of the market-share triopoly. In McCalla's terms, the oligopoly no longer functioned because the elimination of surplus carryover stocks is equivalent to the destruction of market power.

Table 3. End-of-Season Carryover Stocks: United States, Canada, Australia (1000 metric tons), seasons 1962/63 to 1975/76

Season	United States	Canada	Australia	Total
1962/63	32,529	13,261	628	46,418
1963/64	24,532	12,504	552	37,588
1964/65	22,242	13,962	663	36,867
1965/66	14,565	11,434	453	26,452
1966/67	11,551	15,697	2,191	29,439
1967/68	14,657	18,112	1,402	34,171
1968/69	22,226	23,183	7,259	52,668
1969/70	24,086	27,452	7,217	58,755
1970/71	19,894	19,982	3,404	43,280
1971/72	23,487	15,888	1,448	40,823
1972/73	11,920	9,945	485	22,350
1973/74	6,722	10,089	1,887	18,698
1974/75	8,899	8,037	1,658	18,594
1975/76	14,780[a]	7,376[a]	2,133[b]	24,291

Source: International Wheat Council, *World Wheat Statistics*, 1976.
[a] Estimate obtained from U.S. Department of Agriculture, *Wheat Situation*, May 1976.
[b] Estimate supplied by the Australian Wheat Board, November 1976.

There is, however, an apparent anomaly in the figures of table 3. Given that the market-share constraint was not operating and prices were relatively high, Australia held unusually high carryover stocks in the 1973/74 and 1974/75 seasons. Most of this wheat was hard or prime hard and was concentrated in New South Wales. The AWB has indicated that the 1973/74 carryover was higher than intended due to industrial disputes and transportation problems in New South Wales (AWB 1975). The continuation of these problems, together with requests from some buyers for delayed delivery, were the explanation of the 1974/75 carryover (AWB 1976).

A Model of Triopoly Pricing

We have seen that the United States and Canada are concerned with their joint share of the total export market as well as their individual shares of aggregate North American exports. We have noted that when duopoly pricing is consistently followed, the total market shares of the duopolists cannot be maintained when the residual demand curve facing them shifts towards the price axis, other things being equal. When this occurs the market shares of fringe suppliers increase at the duopolists' expense.

Australia is the third largest wheat exporter. The formation of a triopoly with the United States and Canada is an obvious way in which the market shares of the duopolists can be maintained when the residual demand curve of these three exporters shifts towards the price axis, or when the Australian exportable surplus is large with respect to the residual demand facing the duopolists.

In developing the model we assume the following points: (*a*) The duopolists (the United States and Canada) have a notion of a minimum acceptable share of the export market facing them and Australia, and that one of them (the United States) is prepared to initiate a price war when this minimum is not attainable by negotiation. (*b*) The United States and

Canada have some agreement as to how this market share is to be divided between them. That is, we are assuming that there are two relevant market-share curves. The first is a curve that shows how the market facing the triopolists is divided between the North American participants and Australia. The second market-share curve defines how the North American share is split between the United States and Canada. The latter curve is analogous to the market-share curve in Taplin's model. (*c*) Canada attempts to maximize revenue and, primarily because of this, is the price leader. It is not essential to our theory that one participant is always the price leader. Some situations in which other participants will take over leadership are discussed in the section on price determination and the triopoly. (*d*) Wheat is homogeneous and, for simplicity, the supply curves of competing exporters (including Australia) are perfectly inelastic. (*e*) The duopolists hold surplus stocks.

The manner in which the triopoly can form is illustrated in figure 2. As a starting point, we consider a stable duopoly situation as shown in figure 2a. The world demand curve is D_wD_w. The residual demand facing the major exporters is D_rD_r. Subtracting the Australian exportable surplus from D_rD_r yields the residual demand curve facing the duopolists, DD. The broken line labelled D_2D_2 represents the market-share curve which divides the residual demand facing the three major exporters between the duopolists (to the left) and Australia (to the right). The other market-share curve, D_1D_1, divides the North American share between Canada (to the left) and the United States (to the right).

The market price, P_1, is set by Canada at the point of unitary elasticity (E) on the residual demand curve facing the duopolists. This is a stable duopoly solution, because the Australian share (bc) of the residual demand facing the three countries is less than that permitted by the duopolists (ac). The manner in which the price is determined and the North American share divided between the United States and Canada was discussed in the second section of the paper in the context of Taplin's model. In order to keep figure 2a as clear as possible, the duopoly model is not explicitly shown in the diagram. However, we would like to point out that D_1D_1 does not in general correspond to the duopoly market-share curve drawn in figure 1.

Consider now a shift toward the price axis

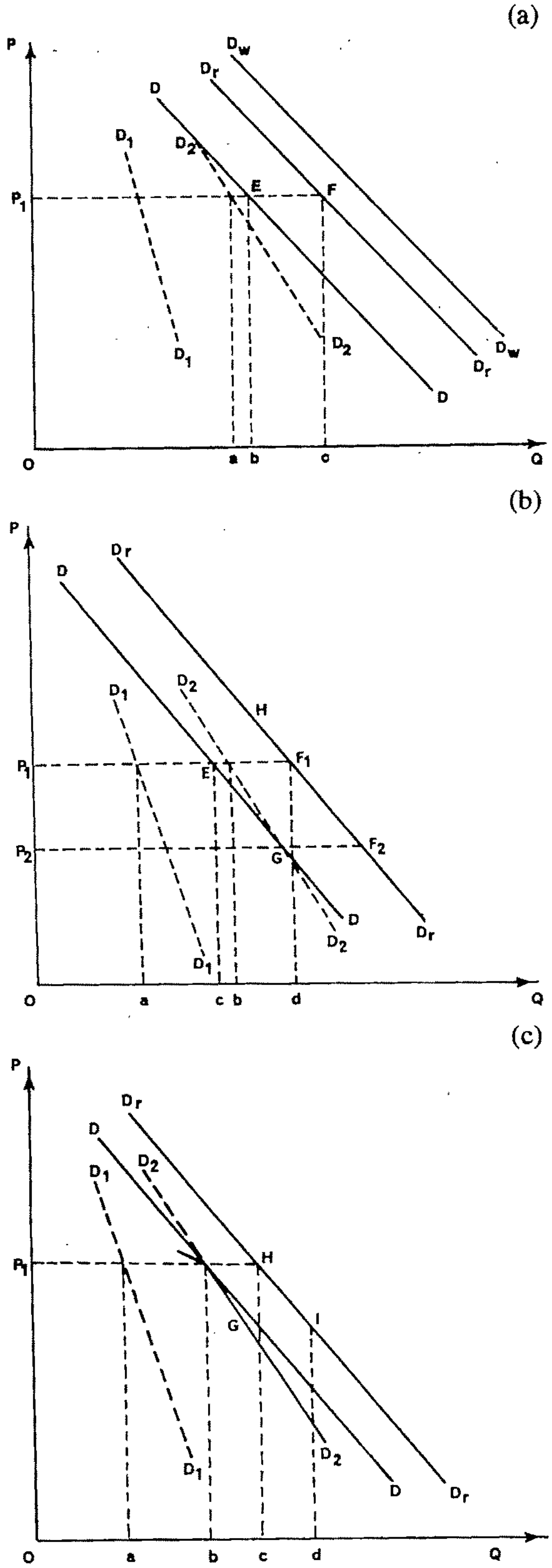

Figure 2. The formation of triopoly pricing

of the residual demand curve facing the three major exporters D_rD_r, as shown in figures 2b. and 2c. This could be caused by an increase in wheat production in importing countries, an increase in the exports of minor exporters, or both. Figure 2b shows how duopoly pricing can break down under such circumstances and how a triopoly can result. Figure 2c shows how a stable triopoly can function.

In figure 2b, the exportable surplus of Australia is unchanged, and DD is the new residual demand curve facing the duopolists. The two market-share curves, D_1D_1 and D_2D_2, are also different from those in figure 2a and reflect how the duopolists view their shares of the new, smaller export market. This situation shows that duopoly pricing is unstable because the market-share curve (D_2D_2) defining the split of the residual market between the North American exporters and Australia lies to the right of the residual demand curve facing the duopolists (DD) at the point of unitary elasticity (E) on the latter curve. This indicates that if Australia pursued a policy of pricing to sell all its exportable surplus, the market share of the United States would be eroded at most prices set in following a duopoly strategy.

The evidence suggests that it is primarily the U. S. share of the total export market that is eroded by Australian pricing policies and that it is essentially the United States which takes retaliatory action. For example, during the 1964/65 season, the Australian exporting policy mainly affected the U.S. share of the export market facing the triopolists (see table 2). In 1965/66 the United States retaliated by pricing its No. 2 Hard Winter wheat below that of Australian faq over a period of twelve months. This was a significant price reduction because Australian faq is an inferior grade to No. 2 Hard Winter. Canada matched the initial price decrease but did not reduce the price of its hard wheats below the government-guaranteed price. However, for the purposes of our analysis, we assume that all price decreases are fully matched. It should also be noted that it was the U.S. proposal that the IGA-pricing provisions be suspended. This prompted the AWB press release quoted above.

To return to the model, suppose Canada were to pursue the revenue-maximizing strategy and set the price at P_1. At this price the market share of the United States (ac) is less than the share it regards as acceptable (ab). Under these circumstances, price stability cannot be achieved in our model until some combination of two basic compromises is reached.

The first compromise is that the duopolists reconsider their notion of a minimum acceptable share of the residual market. This requires that the market-share curve D_2D_2 be shifted to the left of DD, so that it intersects DD at E. This implies an appropriate adjustment in D_1D_1. The evidence from the two price wars and the market shares (table 2) indicates that this solution is not seriously considered by the duopolists.

The alternative solution, which is supported by the historical evidence, involves Australia reducing its exports until DD lies to the right of D_2D_2 at the market price. That is, a market-share triopoly is formed by initiating a limited price war. To be effective in pressuring an unwilling new entrant, the industry demand curve D_rD_r must be inelastic; that is, the price cutting occurs below H, the point of unitary elasticity on D_rD_r. Under our market-sharing assumption, the lower limit to the price cutting, P_2, is determined by the intersection of DD with D_2D_2 at G. Faced with this prospect, Australia agrees to restrain its exports and the market-share triopoly forms. Having absorbed the new entrant, oligopoly pricing now occurs along the demand curve facing the triopolists D_rD_r. The price leader, following its revenue-maximizing objective, attempts to set the price at H, the point of unitary elasticity on D_rD_r. Providing this price is less than the price of the previous season, there is no problem associated with pricing at H. This follows from the market-share assumption—the other participants will always match a price reduction in order to maintain their market shares. If, however, the price corresponding to H is higher than that of the previous season, the new price is determined by the mechanism outlined by Taplin. The new price, set by the leader, is the highest price which will be followed by the United States and Australia, its upper limit corresponding to the price associated with H.

A stable triopoly solution is shown in figure 2c. We assume that the market price P_1 is set at the point of unitary elasticity (H) on the residual demand curve facing the triopolists. Australian exports have been reduced to the point where, at P_1, the share of the United States (ab) is determined by the two market-share curves, and the share of Canada (oa) by the market-share curve D_1D_1. The Australian

share is the residual quantity (bc). The kink is placed on the market-share curve which defines the manner in which the residual market facing the triopolists is split between the North American participants and Australia (D_2D_2). This is the curve along which the historical price wars have occurred. The pricing mechanism associated with the kink was described in the preceding paragraph and is essentially the mechanism outlined by Taplin. Because the Australian wheat stabilization scheme guarantees the price of a given quantity of exports, Australian participation in the triopoly can be seen as minimizing government payments under the scheme as exports are reduced and a major fall in prices prevented.

Implicit in the preceding discussion is that the North American exporters can initiate a price war in order to maintain their minimum market shares. Given that the supply of wheat from production in each season is fixed, the only way exports can be increased beyond production in support of the notion of minimum market shares is by depleting surplus stocks. Stockholding is therefore one essential requirement for the operation of a market-share oligopoly in the world wheat market. We shall now consider in some detail the notion of the elasticity of supply from stocks in the context of the triopoly. We shall take a circuitous route in approaching this concept in order to illustrate an important aspect of the model we have developed.

What is the elasticity of demand for Australian wheat in the context of the stable triopoly solution shown in figure 2c? Imagine that Australia reduces its prices to the extent that the residual demand curve facing the duopolists, DD, now intersects the market-share curve D_2D_2 at G. Under our assumption of fixed market shares, we expect the duopolists to reduce prices until the market share of the United States is restored at the point G on D_2D_2. This corresponds to the point I on the industry demand curve; and, at this lower price, additional (cd) units of wheat are sold from the surplus stocks of the United States and Canada. Since the market shares remain constant throughout the price cutting, the elasticity of demand faced by all participants is that associated with the industry demand curve (D_rD_r) below H. That is, the elasticity of demand facing the participants in the market-share oligopoly is less than one and equal to that of the industry demand curve at every price. (For a discussion of a similar phenomenon in the context of revenue maximizing, market-sharing industrial oligopolies, see Stigler, p. 42.) This is why price wars are of a limited nature and the price generally stays at the kink.

Suppose we now attempt to answer this question using a naive application of the market-share formula:

$$\delta_t = (\delta/k_t) - (E\cdot k/k_t), \tag{1}$$

where δ_t is the elasticity of demand facing Australia, δ is the price elasticity of the industry demand curve (D_rD_r), k_t is the Australian market share, k is the combined market share of the United States and Canada, and E is the supply elasticity of the United States and Canada.

Consider the first term on the right hand side of (1). From our revenue-maximizing assumption for the stable triopoly solution (figure 2c), $\delta = -1.0$. Using a typical value of 0.3 (from table 2) for the Australian share, k_t, the first term equals approximately -3.33. Providing the supply elasticity of the United States and Canada is positive, this approach suggests that the elasticity of demand facing Australia is, in absolute terms, greater than 3.33; that is, Australia faces an elastic demand, a result at variance with that obtained above.

This approach cannot be used to place a lower bound on the elasticity of demand facing Australia, because, as we have shown above, the United States and Canada respond to price cuts initiated by Australia (in attempting to increase its market share) by increasing their exports rather than reducing them. This implies that their elasticity of supply from stocks has a negative sign; therefore, the negative of the second term in equation (1) is of the opposite sign to that of the first term and, hence, reduces the absolute value of the expression to below 3.33. Equation (1) cannot be used to estimate the elasticity of demand facing Australia in an oligopoly situation, unless the estimate of the elasticity of supply from stocks is calculated using all the restrictions implied by the market-share assumptions. (For an application of this formula to a stable oligopoly, see Etherington.)

Using the results of our analysis, we can solve equation (1) to obtain an estimate of the elasticity of supply from stocks of the North American exporters, such that the elasticity of demand facing Australia is equal to that of the industry demand curve. To be quite general, we assume $\delta = \delta_t$ and that $k + k_t = 1$. Substituting

these values into (1) we obtain the result $E=\delta(=\delta_t)$; that is, the elasticity of supply from stocks is exactly the same as the elasticity of demand (in both sign and magnitude) of the point on D_rD_r under consideration.

From this analysis we conclude that the elasticity of supply from North American stocks is negative during price wars and that, during such occurrences, the demand facing the participants in the market-share oligopoly is inelastic. On the other hand, under "normal" conditions, namely, when the oligopoly is adjusting its price and quantities to shifts in the industry demand curve (D_rD_r), the elasticity of supply from stocks is positive. Future econometric studies of demand in the world wheat market will need to recognize that the usual "small country" assumption that demand for Australian exports is elastic, can break down under triopoly pricing. Such studies will need to model this phenomenon.

Price Determination and the Triopoly

We shall now use the model to show how the triopoly can break down when faced with an episodic increase in demand (as occurred in the 1972/73 season). We then discuss some of the possible ways in which the triopoly can be restored.

Suppose there is a shift to the right of the residual demand curve facing the triopolists (D_rD_r), as shown in figure 3. The price in the previous season was P_1; the total exportable surplus (current production plus surplus stocks) of the triopolists is oc, composed of

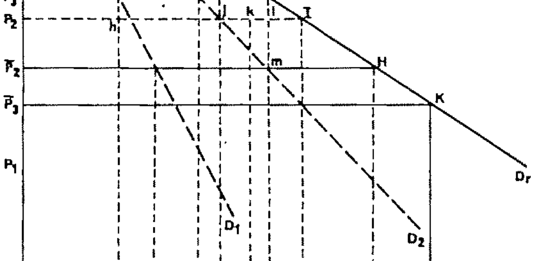

Figure 3. The breakdown of triopoly pricing. Market share scale is Canada; United States; Australia 0.31 0.30
0.39

the sum of the exportable surpluses of Canada, the United States, and Australia: oa, ab, and bc, respectively. For the purposes of illustration, we assume that the exportable surplus of the United States is greater than that of Canada, which is greater than that of Australia; that is, $ab>oa>bc$. The market-share curves D_2D_2 and D_1D_1 are the same as defined above and the point of unitary elasticity on D_rD_r is H. Because the total exportable surplus of the triopolists is oc, only prices corresponding to points to the left or equal to I are feasible.

In this example, the price leader, Canada, will attempt to maximize its revenue by setting the price at P_3, the highest price at which its exportable surplus (including surplus carryover) intersects the market-share curve D_1D_1,(g). At this price, Australia does not have enough wheat to obtain its full market share, and would export the quantity ef, which is equal to bc. The United States would export only the quantity ae, which is less than its exportable surplus (ab). In order to hold the price at P_3, the United States would need to hold surplus stocks of eb. However, there is no incentive for the United States to hold any surplus stocks, since the elasticity of demand facing the United States is equal to that of D_rD_r, which is elastic. Hence, the United States will drop the price to P_2 where it holds no stocks. The exports of Canada and Australia are the same as at price P_3.

The reduction in price from P_3 to P_2 costs Canada the area defined by P_3ghP_2, costs Australia the area defined by $iJlj$, and the United States gains the difference between the areas $gijh$ and $jkbe$. The market shares at P_2 are defined by the total exportable surpluses of each exporter and do not lie on the market-share curves. The result generalizes easily.

Under our assumptions, whenever selling the combined exportable surplus of the triopolists yields a price (say, P_2) which corresponds to an elasticity on the residual demand curve that is greater than unity, the world price will equal this price, and the quantities sold by each of the triopolists will not, in general, lie on the market-share curves; that is, a result similar to the one described above will be obtained. This is because at any price above P_2, at least one of the triopolists will have to hold surplus stocks; however, there is no incentive to hold reserves because each triopolist faces an elastic demand curve and each will sell all its exportable surplus. The opening statement of this paragraph, there-

fore, defines the conditions under which the market-share triopoly breaks down. The variability of the market shares of each of the triopolists after the 1972/73 season is in agreement with the conclusions obtained from our analysis.

From the preceding discussion, it is clear that a necessary condition for the formation of the triopoly is that exporting the combined surpluses of the triopolists (oy) yields a price, say $\bar{P}_3$, which corresponds to a point, K, on the residual demand curve facing the triopolists (D_rD_r) that has an elasticity less than unity (see figure 3). In this event, the new price would be established at $\bar{P}_2$, corresponding to the point of unitary elasticity, H, on D_rD_r, if the price of the previous season is higher than $\bar{P}_2$ (say P_2), or slightly below or equal to $\bar{P}_2$, if the price of the preceding season is below $\bar{P}_2$ (say P_1). The triopolists hold combined stocks of xy at the new price, $\bar{P}_2$. The mechanisms by which this is achieved have been discussed above and in the preceding section. Providing that each of the triopolists has an exportable surplus in excess of the exports defined by the intersections of the line $\bar{P}_2H$ with the two market-share curves, each triopolist exports its market share and the kink is established (as before) on D_2D_2 at the point m.

Many interesting solutions are possible if one or more of the triopolists do not have an exportable surplus large enough to obtain its full market share at $\bar{P}_2$. We shall consider in some detail what our assumptions and model can predict if the price leader, Canada, cannot obtain its full market share at $\bar{P}_2$. We assume, for the purpose of discussion, that the Canadian exportable surplus is oa as in figure 3.

Suppose that the price in the previous season was P_2. In this event, Canada will not assume leadership and reduce the price; however, at this price, both the United States and Australia face an elastic demand curve and one of them will assume leadership and reduce the price to $\bar{P}_2$. At this price, the United States and Australia can export az more than their market-share curves would indicate. In this event, we assume that the United States and Australia collude and agree to divide it in some manner. Suppose, now, that Australia has only enough wheat for it to obtain its share of az, with none left over as surplus carryover, so that there is no possible violation of the market-share agreement between the United States and Australia. The United States has a carryover equal to xy, by assumption. In this case, we place the kink at the point of unitary elasticity H on D_rD_r, because the major factor stopping the United States from increasing its market-share (in the absence of retaliation from the other exporters) by reducing its carryover is that it faces the inelastic part of D_rD_r at points below H or prices less than $\bar{P}_2$.

The Future of the Triopoly and Wheat Prices

In this section we argue that if the major exporters continue to be concerned with their relative market shares (as is likely), it is inevitable that the triopoly will reform, stocks will accumulate, and lower prices will prevail; however, prices will be more variable, and possibly higher, than before 1972/73.

We have identified two basic conditions for the formation of the market-share triopoly in the future: first, that the major exporters possess the willingness and ability to hold stocks which can be used to exert market power in preserving market shares; second, that the exportable surplus of the triopolists is large relative to the residual demand curve facing them, in the sense outlined above. On the first point, we argue that Australia has joined the United States and Canada in being able to hold carryover stocks.

McCalla observed in the context of the previous duopoly that "as with most collusive agreements, informal and unwritten rules probably constitute the core of the duopoly arrangement" (p. 722). He relied, in part, for his explanation of wheat pricing arrangements on reported statements of officials and his own off-the-record discussions with them. The present authors have produced similar evidence of collusion in 1969 with the AWB press statement quoted above. We also have become aware that the quarterly meeting between the United States and Canadian wheat authorities (McCalla, p. 722, fn. 7) now includes Australia. This means that the informal mechanism is currently operating.

The Australian storage capacity is a direct result of the silo construction program carried out in 1969. Using a simple statistical inference model, we estimate Australia's excess capacity to be approximately 5.4 million tonnes.[4] Recent experience has shown that once

[4] We defined the excess capacity as the maximum carryover that can be held by the AWB and still permit the acceptance of the current crop into the silo system ninety-five years in one hundred. The figure was arrived at by assuming: (*a*) normality and stationarity of the probability distribution of Australian yields; (*b*) that the

stocks accumulate, the major exporters are prepared to initiate severe supply controls in an attempt to reduce the level of the carryover. Subject to some qualification, this is an important factor affecting future price stability. As we have shown, the extent to which the triopolists do stabilize wheat prices in the face of episodic increases in demand is largely dependent upon their surplus stocks.

Despite this observation, we believe that the major producers will hold large carryovers in the future in order to maintain revenues when faced with inelastic demand; for example, when there is a contraction in the export market and there exists a large exportable surplus.

The major exporters can exercise some control over supply in the long run through their agricultural policies, which are flexible in the sense that they can be changed each year in response to the price and stock situation. However, in the past these policies have failed in their major objectives, namely, the maintenance of high prices. Abstracting from the general issue of excess capacity in agriculture, we believe that there are two important reasons for this failure: the difficulty of predicting import demand and the likelihood that increases in the exportable surplus and contractions in the residual market are highly correlated. In periods of high prices and low stocks, the major exporters expand their production partly because they believe that high prices will persist, and partly because if one exporter expands production (and exports) alone, the market shares of the others will fall. However, the high prices also provide an incentive for the importing countries to expand production. This results in a contraction of the export market at the same time as the exportable surplus is increased. Depending on the size of the relative movements, the major exporters may have to hold stocks to maintain price at the point of unitary elasticity on the residual demand curve facing them. There is evidence that this phenomenon has occurred in the past, and we believe it is an important factor in the current decline in prices.[5]

There are two arguments for speculating that prices in the foreseeable future may be higher than before 1972/73. While these are not conclusive arguments, they are worth considering. There appears to have been substantial policy changes with respect to wheat imports by some major consuming countries, in particular the Soviet Union and China (Cochrane, Johnson 1975).

In the past, only a fraction of a short fall of production relative to desired consumption was imported in seasons of short crops. Recently, wheat has been imported to offset the deficit without making adjustments in the livestock industries. This implies that in years of small crops in these countries, the residual demand curve facing the major exporters could shift to the right to a greater extent than in the past under similar conditions, and that as a consequence prices would be higher on average.

Such increases in demand are episodic and are therefore likely to influence the stock holding policies of the major exporters in the future, with the major exporters holding speculative stocks to service the shortfall. For example, Taplin (p. 43) argued that an important factor explaining the large Canadian wheat stocks in the sixties was the possibility of windfall sales to the Communist bloc, in particular the Soviet Union. This strategy will tend to reduce the variability of future prices.

In comparing duopoly pricing and triopoly pricing using linear demand functions, it is clear that the point of unitary elasticity on the residual demand curve facing the triopolists occurs at a higher price than the point of unitary elasticity on the residual demand curve facing the duopolists, other things equal. Given such demand functions, this alone would indicate that prices will be higher under triopoly pricing than if duopoly pricing policies were pursued. Irrespective of the form of the demand function, a shift that causes stocks to be cleared and prices to be formed in a competitive fashion will result in a price above that at the point of unitary elasticity. Given moderately frequent large shifts to the right in demand and the evidence that the major exporters are prepared to initiate supply controls and reduce their stocks, the frequency of stock withdrawals is likely to increase. Such events would suggest higher and more variable prices.

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capacity of the grain handling system is 20.2 million tons (the 1974/75 season figure); (c) that the highest area ever sown (10.85 million hectares for the 1968/69 season) is sown each year. An allowance was also made for farm retention and storage in the transportation system.

[5] For example, Johnson (1973, p. 134) has commented on the United States as follows: "The relatively large area in 1967/68 was due, probably, not only to the changes in the wheat program but the relatively favourable price of wheat in the previous year and the general, but mistaken, impression that the world was in for a period of stringency in the food grains."

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The 1973 Food Price Inflation

Albert Eckstein and Dale Heien

This study analyzes the major causes of the food price inflation of 1973. In the approximate order of their importance, those causes were found to be domestic monetary policy, government acreage restrictions, the Soviet grain deal, world economic conditions, devaluation of the dollar, and price freeze II. Econometric models of the livestock and feed grains and meal economies were used to decompose the price increase into the various causes given above. The study also details and analyzes events and policy actions taken during the 1971–74 period.

Key words: food prices, government policy, inflation, international trade.

The 1970 corn blight started in motion a chain of events that culminated in the greatest food price inflation in the United States since the Civil War. Central to the explanation of this inflation was the movement in the prices of livestock products and feed and food grains. U.S. grain and meal prices were highly influenced by international market conditions in general and Soviet purchases in particular. At the same time, domestic agricultural policy concentrated on further restrictions in output at a time when worldwide stocks were diminishing rapidly. International crop failures and rapid income growth further reduced the stock-consumption ratios. And two successive devaluations of the dollar contributed more to a tightening of demand. Rapid growth of income, as the U.S. economy moved out of the 1971 recession, was the key factor in explaining meat price increases. Radically higher feed grain and meal prices, along with interference of domestic price controls, provided livestock producers with little incentive to expand output in the face of this rapidly accelerating demand.

The compounding of inflationary conditions of the early seventies by the food price inflation of 1972–74 brought to light a number of inadequacies in the integration of food and agricultural policies with other economic policies. Several accounts have described the sequence of events that occurred and how various policy decisions, the weather, and international events interacted to shape the inflation. (See, for example, Hathaway, Johnson, Nelson 1974, 1975, and Schnittker.) Although these accounts were well done and timely, none attempted to quantify the roles these factors played. This paper attempts to fill that void. It is desirable for three reasons. First, such an analysis reveals the mechanics of food price inflation, considerably different than that which occurs in the industrial sector. Given the recurring interest in food and agricultural policy, and given the impact of food prices on the nonfarm economy, an improved understanding of this process is desirable. Second, quantification puts the various causal factors in their proper perspective. One major result of this analysis is that the degree of coordination among various policy instruments and the interdependence of their economic targets becomes more evident. Third, disagreement now exists concerning the relative importance of the main causes.

The methodology employed here utilizes a set of econometric models for the U.S. livestock and feed grains sectors.[1] These models are cast into the reduced form in elasticity

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[1] Due to space limitations, only the main relations for the feed grains sectors are presented. The livestock subsector models are presented in Heien 1975, 1976, 1977b; and Heien, Kite, and Matthews. The models used were estimated with data from the 1950–70 period, except the corn and soybean meal export demand relations which used data from the 1956–74 period. Prediction interval tests for 1971–74 were then conducted in order to validate these models. The results of these tests for the livestock models are reported in the references above; hence, the predictions made by the models used in this study are *ex ante* predictions. They do, however, have the important advantage of using the correct values of the exogenous variables.

mode so that the percentage of change in the endogenous variables can be decomposed into the percentage of change in the various exogenous causes. This decomposition is done, first, for the feed and food grains models separately, so that the reader may better understand the role of exports, livestock numbers, prices, and other factors in the determination of feed grain and meal prices. Next, the livestock economy is analyzed in a similar manner, with grain and meal prices, along with income and nonfood prices, taken as exogenous. Finally, the two sectors are interfaced and the quantification of the various causal factors emerges. Our interest is not to evaluate the ability of the models to simulate conditions during the period under study, which has been done elsewhere, but rather to decompose the overall price rise into its proximate causes. However, before these models can be applied, the exogenous variables must be linked to policy actions. For example, the restrictive acreage policy of 1972 must be translated into actual acreage; the events must then be fed through the model. The bulk of this paper is concerned with a description of these events and the manner in which they were translated into exogenous changes in the model. In the next section, the background and setting for the food price inflation of 1973 is provided. The third section goes on to examine the 1973 inflation in detail, to analyze and quantify its basic determinants. The final section summarizes the analysis and assesses policy implications.

Background and Policy to 1973

It is useful to outline briefly the unfolding of events beginning about 1971. This is consistent with the feedback dynamics of the livestock sector and illustrates how government policy in the food price area became increasingly a rearguard action. During the first half of 1971, the food component of the consumer price index (CPI) rose 7.6%. (Unless otherwise stated, all percentages are at an annual rate.) As a result of the corn blight and increased soybean exports, feed costs rose substantially, having a depressing effect on livestock production—already falling as pork producers entered the liquidation phase of the hog cycle. Pressure on the dollar, rising food prices, and renewed inflationary forces elsewhere in the economy precipitated a general wage and price freeze announced on 15 August and followed by a 10% devaluation in December. As a result of bumper crops and worldwide recession, U.S. farm exports had turned downward, with little expectation for improvement throughout 1972. Based on this assessment, the government initiated major efforts to expand grain exports. At the same time, the administration began shaping the 1972 crop year program, providing for a set-aside target to decrease output by 8%.

The Soviet grain deal, and the manner in which initial Soviet purchases were made, turned out to be of critical importance to the behavior of U.S. grain prices after mid-1972. The main element of the initial agreement between Nixon and Brezhnev, discussed at the Summit meeting of 28 May 1972, pertained to the extension of $750 million credit to the Soviets for purchases of U.S. grain over a three-year period. No specific mention was made of the kinds of grain the Russians planned to buy, but U.S. officials generally believed most of the immediate Soviet requirements were for corn rather than wheat, since the Russians had just purchased 3.5 million metric tons of wheat from Canada. Both the White House and the U.S. Department of Agriculture were apparently unprepared for the speed and finesse with which the Soviets would commence their purchases. A key factor in the consummation of sales between the Soviets and major grain companies was the continuation of the U.S. export subsidy on wheat. Without a guarantee by the USDA that the subsidy would continue, grain companies would have had to risk buying necessary grain at rising prices to meet delivery to the Russians at the fixed contract price. The subsidy's continuation was no doubt an important element in the size and price of grain sales to the Soviets during this period.

Whatever was known about actual activities apparently was not shared widely within the executive branch of government or disseminated to the public (Trager, p. 39). Thus, knowledge of Moscow's need for foreign wheat was effectively kept from the market, and prices remained low while the Soviets consummated huge transactions during the summer. As the grain companies entered the market, and as the news of the Soviet deal began to be fully understood, wheat prices and the export subsidy shot upward at remarkable rates. The average subsidy on sales to the Soviets was about 30¢ per bushel; and it has been estimated that a total of $132 million was

spent to subsidize the Soviet purchases, while another \$180 million was paid on shipments to other destinations.

In the face of commitments to the Soviets, declining world grain production, and a devalued dollar, the USDA announced on 17 July 1972 a restrictive 1973 wheat program, with acreage set aside at the legal maximum. Options existed as late as August, when a change would have provided increased acreage of winter wheat. By late 1972 prices began to reflect the market pressures as corn prices ended the year up 32% and soybean meal rose 110%. During 1972, the Peruvian anchovy catch was less than half its average—or a feed equivalent of about 10% of the U.S. soybean crop that year. This touched off a worldwide scramble for other high protein supplements, focusing primarily on U.S. soybeans. Poor weather and crop failures in the Soviet Union, mainland China, India, West Africa, and Australia sharply increased the demand for U.S. oilseed products and corn.

To develop a framework for analyzing feed grains, we used econometric models built around supply and utilization tables (see Womack). Assuming production, $\bar{P}$, to be exogenous, the U.S. corn economy can be modelled as

$$(1)\qquad FE = \bar{P} + \bar{I}_{-1} - \bar{F}\bar{O} - I - X,$$

$$(2)\qquad I = f(D, p),$$

and

$$(3)\qquad X = f(p, r, z),$$

where FE is feed use, I is inventory, FO is food use (exogenous), X is exports, D is demand ($= FE + FO + X + I$), p is price, r the exchange rate, and z stands for other (exogenous) factors. The model is closed by fitting the remaining equation, the demand for feed, as a price dependent equation. This is done in recognition of the fact that feed demand is the major component of corn demand and, given production, that quantity demanded is more or less fixed. Hence, price is the variable which must adjust.[2] The key estimated relations in a model such as the one outlined above are the feed demand and export demand, since stocks and food use are quite small relative to feed use and exports. For corn and soybean meal the demand relations are[3]

$$(4)\qquad PC = \underset{}{.52311} - \underset{\substack{(4.3)\\1.22}}{.0044FEUC} + \underset{\substack{(3.0)\\.20}}{.074LSN} + \underset{\substack{(1.4)\\.34}}{.0037WLSP} + \underset{\substack{(2.8)\\.22}}{.0668PSM},$$

$$\bar{R}^2 = .73 \qquad D.W. = 1.99$$

and

$$(5)\qquad (PSM/WLSP) = 2.31 - \underset{\substack{(2.2)\\1.04}}{.19QMD} - \underset{\substack{(1.8)\\.43}}{1.98(WLSP/PC)} + \underset{\substack{(2.9)\\.54}}{6.21(WLSP/WRMP)} + \underset{\substack{(2.9)\\.30}}{.026LSN}.$$

$$\bar{R}^2 = .63 \qquad D.W. = 1.16$$

It should be noted that the above relations are inverted feed demand relations, or more correctly inverted factor demand relations. As such, they relate the demand for feed to the marginal value product of feed. Hence, the price of output ($WLSP$) plays a large role in each of the two relations. Its flexibility is .34 and 1.11 for corn and soybeans respectively. The theory of price determination put forward in this paper is one of simultaneous determination of feed grain and meal prices and livestock product prices. However, increases in livestock prices arising out of shifts in demand, for example, will raise the marginal value product of feed. These price increases shift the schedule for feed. When this occurs in a period of tight or fixed feed supplies, the shift will cause substantial increases in feed prices. There seems to be insufficient appreciation of the role of demand for meat products in the explanation of grain price increases during this period. While we are not claiming that all of the price increases for feeds arose from price increases for livestock products which, in turn, resulted from exogenous (to the farm sector) changes in income, we are saying that these changes played a large role. The notion that international events and government acreage restrictions alone drove up grain prices, which in turn drove up meat prices, will not bear scrutiny. Prices equal cost of production only in long-run equilibrium. The manner in which a sector adjusts to that new equilibrium is the subject for analysis here.

[2] For a more detailed discussion of price dependent derived demand curves, see Heien 1977a.

[3] The numbers below the regression coefficients are the t-ratios. The numbers below the t-ratios are the elasticities at the means. Appendix B lists the variables and units of measure.

The export demand relations for these two products are given by

$$(6)\qquad EC = 64.8 - \underset{\substack{(3.3)\\ -.10}}{252.8PC} + \underset{\substack{(5.5)\\ .16}}{178.2PSM}$$

$$+ \underset{\substack{(2.2)\\ 2.45}}{31445.PLX_{-1}} + \underset{\substack{(2.1)\\ 1.63}}{18252.IX} - \underset{\substack{(2.7)\\ -.82}}{.97CPBSE}$$

$$+ \underset{\substack{(1.9)\\ 3.10}}{.44AUX} - \underset{\substack{(3.2)\\ -.77}}{.63CPBSP},$$

$$\bar{R}^2 = .98 \qquad D.W. = 3.2$$

and

$$(7)\qquad QMX = -13271. - \underset{\substack{(2.0)\\ .17}}{268.6 \cdot PSM}$$

$$+ \underset{\substack{(2.5)\\ .32}}{11546.(PC + DU)} - \underset{(5.0)}{.76OMF} + \underset{\substack{(5.2)\\ 5.5}}{.53AUX}$$

$$+ \underset{\substack{(2.1)\\ .08}}{8505.PLX_{-1}} - \underset{\substack{(3.0)\\ -}}{737.DD} + \underset{\substack{(5.6)\\ .62}}{1169.ZG.}$$

$$\bar{R}^2 = .98 \qquad D.W. = 2.38$$

The above equations were used to analyze the grain and meal prices for the 1972 crop year (1 Oct. 1972–30 Sept. 1973). This period is preferable to either calendar year 1972 or 1973, since it most closely parallels the price increases in the livestock sector. The decomposition of these prices is accomplished by multiplying the percentage of change in each of the right hand side variables by the elasticity for that variable. The resulting product is the contribution of that variable to the total change in the dependent variable. The results are given in table 1.[4]

Next, the changes in the total production of corn and the quantity of soybean meal produced were decomposed. As mentioned above, the administration launched a restrictive acreage policy in February 1972. This policy was more effective than the 1.2% decline in total output might indicate, since planted acres of corn (the policy target) fell by 9.5%. As a result of decreased acreage and other factors, yields rose by 9.1%, resulting in the above mentioned decline in total output. Under the acreage program, farmers signed up to set aside 37 million acres of 1972 feed grain land, approximately double that of the previous year. Of this total increase of 18 million set-aside acres for feed grains, about 12 million acres was corn land. Planted acres of corn fell by 7 million. Hence, the total decrease in acreage was ascribed to government policy. It could be argued that the effect of government policy was even greater, since the set-aside exceeded the actual decline in planted acreage by five million acres, the exact amount by which planted acres increased the following year. Decreases in acreage, of course, tend to increase yields as farmers work the land more intensively. Based on estimates by Houck and Gallagher, the elasticity of the corn yield with respect to harvested acres was set at −.24. Attributing the difference between planted and harvested acres to weather, the decrease in total production can be divided between government policy, which by itself would have caused a decrease of 10.7%, and other factors—fertilizer prices, weather, and supply response variables—which would have caused an increase of 9.5%.

The final decomposition for corn and meal price is given in table 2. Included under the heading of foreign demand factors are PLX_{-1}, *IX*, *DU*, and *AG*, while *CPBSE*, *AUX*, and *CPBSP* comprise foreign supply factors. Because the third part of table 1 pertains to corn exports but excludes those to the Soviets, exports of corn to the USSR were treated as exogenous. The corn price equation is relatively accurate and requires little explanation. The rather large 46.8% error in the soybean meal price is not totally unexpected, given the overall price increase. Part of this error is undoubtedly due to anchovy catch shortfall and the news of poor crops elsewhere in the world. However, some must also be due to devaluation effects. Due to lack of variability in the exchange rate over the historical period of fit, it was not possible to measure the impact of U.S. meal price *vis-à-vis* other exporters' meal price, although the equations do capture the own and cross-price effects for corn and meal. The appropriate devaluation rates were applied to the own and cross-price effects. The effects, however, were virtually self cancelling. In order to compensate for this omission in the ensuing analysis, half of the error in the

[4] Table 1 introduces a new variable, *TEC*, total exports of corn which is equal to *EC* plus (exogenous) corn exports to the USSR. Since the equations are linear, the elasticities reported in (4)–(7) are computed at the mean of the 1950–70 period. For the 1972–74 period, the variables (especially prices) took on values considerably greater than the means, which implies that the elasticities varied considerably from those given above. This was checked by comparing single equation solution errors with those errors given in the tables. They were quite close.

Table 1. Decomposition Analysis for the Prices of Corn and Soybeans and for Corn and Soybean Exports, 1 October 1972—30 September 1973

Variable	*TPC*	*TEC*	*LSN*	*WLSP*	*QMP*	*QMX*	Other	*PC*	Error
Corn:									
(1) Elasticity	−1.73	.35	.29	.77	−.35	.13			
(2) Percentage of change (actual)	−1.2	45.8	−3.7	37.2	−1.7	24.0		45.1	
(3) = (2) × (1) Contribution	2.1	16.0	−1.1	28.6	+.60	3.1	.5	49.8	−4.7
Soybeans:								*PSM*	
(1) Elasticity	−1.02	.24	.42	1.78	−1.73	.62			
(2) Percentage of change (actual)	−1.2	45.8	−3.7	37.2	−1.7	24.0		153.9	
(3) = (2) × (1) Contribution	1.2	11.0	−1.6	66.2	2.9	14.9	16.2	110.8	43.1
Variable	*PC*	*PSM*	PLX_{-1}	*IX*	*CPBSE*	*AUX*	*CPBSP*	*EC*	Error
Corn Exports:									
(1) Elasticity	−.10	+.16	2.45	1.63	−8.2	3.10	−.77		
(2) Percentage of change (actual)	45.1	153.9	3.1	5.5	−1.25	2.1	−15.0	45.8	
(3) = (2) × (1) Contribution	−4.5	24.6	7.6	8.9	1.0	6.5	11.6	55.7	−9.9
Soybean Exports:	*PC*	*PSM*	*DEV*	*DU*	*QME*	*AUX*	PLX_{-1}	*ZG*	*QMX*	Error
(1) Elasticity	.32	−.17	−.17	.08	.8	5.5	.08	.62		
(2) Percentage of change (actual)	45.1	153.9	−10.	−55.1	13.5	2.1	3.1	0.0	24.0	
(3) = (2) × (1) Contribution	14.4	−26.7	+1.7	−4.4	10.8	11.6	.2	0.0	7.5	16.5

meal price equation was ascribed to devaluation effects. Also of considerable importance for feed and food grain prices was the extent to which the Common Market countries and Japan were insulated from the effects of price increases. The European Economic Community (EEC), through the variable levy system, "protects" its members from high world prices for corn, rice, wheat, sugar, and several other commodities. Since these importers do not pay market prices, they have no incentive to reduce consumption, as was evidenced by the levels of imports for these commodities during the 1972 crop year. This implies that for markets to clear, other nations of the world must absorb even higher prices (Nelson 1975, pp. 23–33). Johnson (pp. 33–34) has estimated that 35% of the grain price increases were due to these policies. As noted above, our import demand relations were fit over the 1956–74 period. For corn, the relatively high income and animal number elasticities (1.63 and 3.10) and the low price elasticity (−.10) may reflect, in part, these policies. Hence, what we have termed foreign demand and supply includes these EC policies. It can be argued further that "spillover effects" from this policy caused some of the unaccounted error in soybean meal export and price relations.

Food Price Inflation: 1973

By December 1972, the stage was set for the greatest six-month meat price inflation since the Civil War. Real income growth for 1972-IV and 1973-I was especially strong, increasing at annual rates of 7.1%, and 9.0%, respectively. The combination of strong demand pull, as the economy moved well out of the 1971 recession, and the extremely rapid rise in feed costs led to an explosive round of meat price increases in early 1973. By March the CPI for meat, poultry, and fish was up 15% from December. Furthermore, the dollar was coming under increasing pressure and, in February, began a second significant devaluation. This devaluation occurred when the overall economy was operating near capacity and when stocks of agricultural commodities were far below normal (*Economic Report of the President, 1974*, pp. 220–26; Rhomberg, pp. 88–

112). Awareness of the unsatisfactory effects of past agricultural policies led to a realignment of the agricultural policymaking apparatus, as food policy control shifted from the USDA to the Executive Office. Initially, a series of supply augmenting policies was undertaken, including a reversal of the 1973 grain programs set a few months earlier. The shift in emphasis from demand (export) expansion to supply expansion was accompanied by much internal conflict within the administration. In the short run little could be done to increase the supply and lower food prices. Thus, on 29 March 1973, the President imposed price ceilings on beef, veal, pork, and lamb. At the time it was thought that the ceilings would be only temporarily binding, since several factors suggested an easing of meat price increases later in the year. For example, USDA surveys such as *Cattle on Feed* and *Hogs and Pigs* indicated increases of 7% in supplies of beef and pork. However, a June revision would show these figures to be overestimated by four percentage points.

These assumptions were invalidated by the extraordinary rise in exports of grains and oilseed products during early 1973, as USDA projections of exports fell consistently short of the mark. Revisions in export figures were large, and accounted for most of the revision in total disappearance during 1972–74. Export forecasts made in the 1972–73 marketing year for feed grains, for example, were successively revised as follows:

	1972–73 Export Forecast
August 1972	26 million tons
November 1972	32 " "
February 1973	33 " "
November 1973	43 " "
Final actual value	43.1 " "

The underestimation of export demand for soybeans and soybean products and for prices was even more severe. After months of intense pressure exerted on the Cost of Living Council (CLC) and USDA by soybean processors (who had been warning of short supplies), the Council of Economic Advisers (CEA) began analyzing the feasibility of imposing export controls on agricultural commodities in May 1973 (General Accounting Office 1974, p. 30). Shortly thereafter, in June and July, export monitoring and then export controls were put into effect on oilseed products. By June pressures for a return to full price controls had grown substantially. Hence, a second freeze, not to exceed sixty days, was announced. Prices at the farm level were exempted, but cost "passthroughs" were not allowed.

At their inception, it was felt that meat price ceilings would not interfere with production plans, since prices would remain sufficiently high in relation to production costs (*Economic Report of the President, 1974*, p. 96). However, meat production costs soared, and these costs could not be passed on because of the ceiling. Cattle and hog slaughter and broiler and egg production were down by 7%, 10%, 1.5%, and 6%, respectively. Reports for August indicated that sixty-four packing plants had closed down, and ninety-four packing plants were experiencing slowdowns. The second general price freeze, during the summer of 1973, conclusively demonstrated the inability of such controls to alter the course of a food price inflation stemming from rapidly rising raw product prices. This freeze placed a severe profit squeeze on meatpackers, feedlot operators, poultry and egg producers, grain millers, and oilseed processors. The disruptions in supply which accompanied this experiment quickly forced the lifting of meat price ceilings. In August, upon the lifting of the freeze, food prices rose by record amounts for any one-month period. Although prices declined throughout the remainder of 1973, the second price freeze and the disruptions in production and expectations which it generated had the overall effect of increasing food price inflation in 1974.

On 9 July 1973, USDA announced the 1974 programs for wheat, feed grains, and cotton. There were no restrictions on acreage, and farmers were told that all-out production was the target. (Policy actions for Phases III and IV are given in appendix A.) At the same time, the principal uncertainty about the course of farm prices was related to export demand which, in turn, hinged upon international production developments. The role of foreign sector developments was particularly important by mid-1973, as government-held stocks were virtually nil, and CCC grain under loan was being redeemed rapidly as market prices exceeded loan rates. An export monitoring system administered by the USDA was made a permanent part of the Agriculture and Consumer Protection Act of 1973. During 1973 it was widely recognized that a major factor in the

USDA's erroneous price forecasts stemmed from a consistent underestimation of foreign demand. Policy actions taken in 1973 to expand acreage and production also were based upon rather vague notions about the amount of idled but productive acreage available. (See *Economic Report of the President, 1975,* p. 159.) Though net returns on marginal land may have been insufficient to induce full land use, it is also possible that increased uncertainty generated by various government controls and policies between 1971 and 1974 produced offsetting incentives to production. The meat price ceiling and price freeze in the summer of 1973 were among these policies.

The price freeze on meats resulted in cattlemen withholding animals from placement in feedlots. For the year 1973, beef heifer and steer slaughter fell by 9.9%. This was due strictly to withholding decisions, since the animals were on the range and in the feedlots. It is well known that heifer and cow slaughter react negatively to higher expected prices for feeder calves, while steer slaughter should react positively (see Nelson and Spreen). These effects are incorporated into the estimated structure of the model. However, the price freeze had the effect of raising price expectations above the levels which prevailed prior to the freeze. These prior levels were already high as a result of the price increases in the previous months. Hence, the price ceilings produced a perverse effect, as cattlemen in the third quarter withheld steers as well as heifers. Placements as well as marketings were down, reflecting, among other things, the price expectations effect discussed above. Also, feedlot operators reduced the number of cattle on feed, partly as a result of higher feeder calf prices and partly as a result of higher feed costs. Hence, some stretching out occurred as animals were fed at lower rates. Also, the uncertainty generated by the on-again off-again nature of controls and government policy in general contributed to lack of feedlot demand. In order to account for this phenomenon, it was assumed that one-third of the total decrease in heifer and steer slaughter was due to the price freeze. Another one-third is attributed to feed cost effects, the remainder to equation error.

Using the complete solution to the 140-equation livestock model, it is now possible to group the causes of the price increases by major categories. The four categories employed are: (*a*) domestic price and income effects (*PAO* and *PCENDS*), (*b*) feed costs (*PC* and *PSM*), (*c*) lagged livestock prices and other, and (*d*) unaccounted error. Table 3 presents these groupings for retail price increases. The last line (all livestock products) is the weighted sum—using the percentages as weights—of each causal factor. Combining the results given in tables 2 and 3 gives a final summary of the causes in table 4.

The major cause of the meat price inflation during 1973 was the effect of domestic real income growth, part of which was a result of expansionary monetary policy. Basically, this result is caused by the relatively high income elasticity for beef and demand increases which accompany increased sales in fast food outlets when employment (especially for females) rises. This increase in demand collided with already short supplies in terms of livestock numbers. The "transformation" of these livestock numbers into pounds of beef and pork was further retarded by the sizeable increases in feed costs. Increases in feed costs were strongly influenced by restrictive government acreage policy, the Russian grain deal, world supply and demand conditions (especially EC

Table 2. Grain and Soybean Meal Price Increases by Major Causes, 1972 Crop Year

Variable	Government Policy (*GP*)	Other Supply Factors (*OF*)	Livestock Numbers (*LSN*)	Livestock Prices (*WLSP*)	Foreign Demand Factors
Corn	12.8	−11.6	−1.1	28.6	3.2
Soybean meal	4.4	−1.4	−1.6	66.2	9.6

Variable	Foreign Supply Factors	Soviet Grain Deal	Devaluation	Unaccounted For	Actual
Corn	5.8	9.1	2.2	−3.9	45.1
Soybean meal	18.3	6.4	5.2	46.8	153.9

benefit-cost analysis. This extension utilizes the Weibull probability distribution, a general distribution permitting great flexibility in input values.

The major advantage of this technique is that the analyst need not specify the absolute "highest" and "lowest" endpoints for range values of input data. The Weibull technique is able to use "best estimates" of the endpoints and allows for uncertainty by adjusting the probability of exceeding those values.

Further application of these probability assignment procedures is possible with little cost or effort on the part of benefit-cost analysts. Such applications can substantially improve decision making and resource allocation in the public sector.

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Table 2. Estimates of Net Benefits under Alternative Probability Assignment

$ in Thousands	Set I	Set II	Set III	Set IV
Mean	4830	4958	4628	4181
Standard deviation	596	1241	1719	1822
Median	4827	4942	4646	4318
Range	3252 to 6918	1506 to 9497	−1470 to 9809	−1810 to 9915
P(NB) <0	0	0	0.007	0.022
Coefficient of variation	0.12	0.25	0.37	0.44

ability that the benefit and cost range values are not known with certainty. The mean and median value of net benefits for set II are very close to those of set I; however, the standard deviation and range values for net benefits are significantly larger even with set II's low probabilities. Measures of risk are significantly raised with set II, e.g., the coefficient of variation with set II is double that of set I.

Sets III and IV represent somewhat more adverse evaluation of uncertainty with higher $P(L)$ for benefits and $P(H)$ for costs. $P(H)$ for benefits and $P(L)$ for costs remain at .05 in both sets. In set III, $P(L)$ for all benefits and $P(H)$ for all costs are raised to .2, while only two values, $P(L)$ for recreation benefits and $P(H)$ for operations and maintenance costs are raised to .3 in set IV. Set III and IV probability changes recognize a common bias in benefit-cost studies: overstatement of benefits, and understatement of costs. Set IV demonstrates the impact of further uncertainty for only two major components. In comparison with the base estimates (sets I and II), the mean and median of net benefits are lower with set III and IV probabilities, while standard deviation and ranges are larger. Measures of risk (e.g., the coefficient of variation) rise substantially, as shown in table 2.

An additional piece of information provided in table 2 is the probability of net benefits being less than zero [$P(NB) < 0$]. With the underlying data and assumptions of sets I and II, $P(NB) < 0$ is zero. Given the higher uncertainty reflected in sets III and IV, $P(NB) < 0$ rises to a maximum of 2.2% with set IV. The magnitude of $P(NB) < 0$ is valuable as a measure of absolute downside risk.

Summary

This paper illustrates an extension of the T-N procedure for incorporation of economic uncertainty in

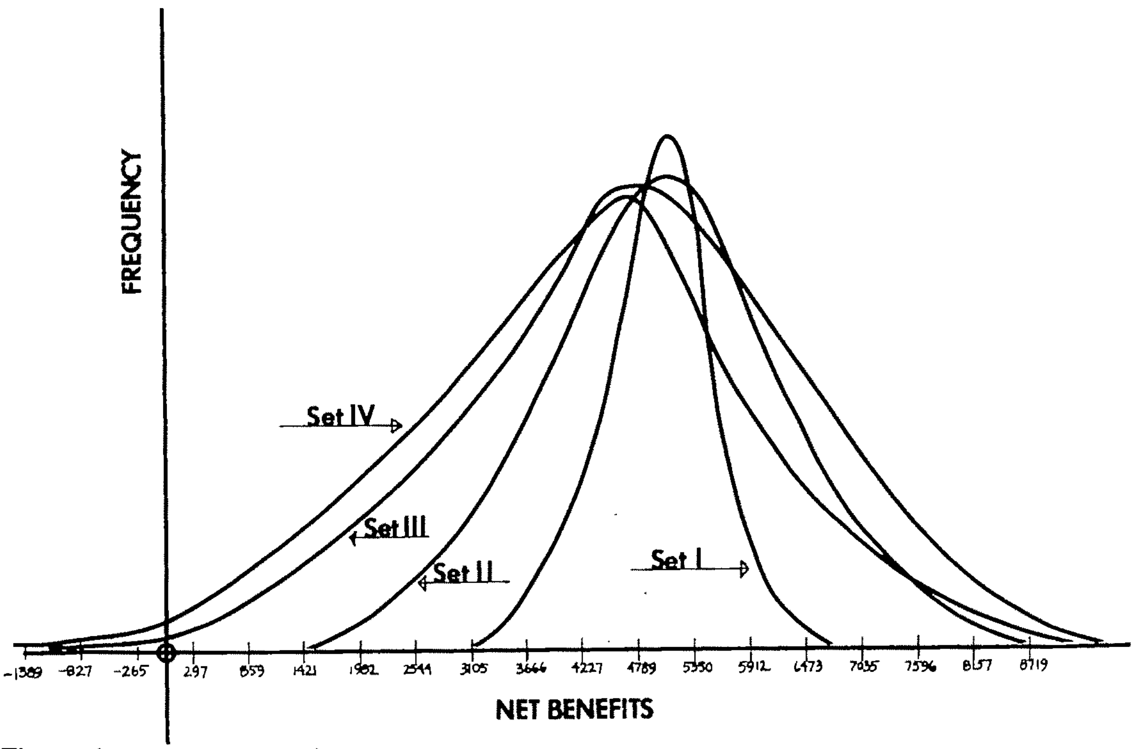

Figure 1.

value *possible* for flood control benefits, i.e., the value that the benefits would never go below (above)," (Taylor and North, p. 639). Answers to such questions provide information on the pessimistic (lower bound) and optimistic (upper bound) endpoints of the triangular distribution (points *a* and *c* in T-N fig. 1). The similar question to be asked using the Weibull distribution has two parts: (*a*) provide me with a likely lower (upper) bound estimate for flood control benefits; and (*b*) what is the probability that the actual value of flood control benefits will be lower (higher) than your estimate?

In the Spewrell Bluff case, the pessimistic value placed on flood control benefits was $847.6 thousand. Implicitly, given the question asked, the probability that the actual value could be lower than that value is zero. With the Weibull distribution, there is no need for analysts to provide the "lowest" possible value for an input variable. A likely lower bound value can always be derived from the research done to obtain the "most likely" value for the input variable. The subjective probability of the input variable falling below the selected lower bound can take account of uncertainty regarding the underlying structure producing the input variable. Suppose the "most likely" value of flood control benefits, given projected land use in the flood plain, is $1,173 thousand and a likely upper bound is $1,300 thousand. The uncertainty regarding future land price, flood frequency and magnitude, and associated economic values can be reflected in the Weibull procedure by the magnitude of the subjective probability of flood control benefits exceeding $1,300 thousand. Both the likely upper bound and its associated probability can be subjected to sensitivity tests. The gain in this procedure is in obviating the necessity to specify the "highest" value. These comments also apply to the lower bound.

The practical difficulties of obtaining answers to these questions from the involved experts are similar for both the triangular and more general distribution. For any distribution, one would need to explain the concepts of probability and endpoints to the experts to elicit the desired judgment estimates (Taylor and North, p. 639, n. 3). Problems of potential bias with such judgment estimate are examined by Moder and Rogers.

The annualized benefits and costs for the Spewrell Bluff Project are summarized in table 1. Three sets of probabilities are presented as alternatives to T-N's implicit probabilities of zero (our set I) for the endpoint values of these benefits and costs. Table 2 lists the output distribution summary statistics (mean, standard deviations, median, and minimum and maximum values of net benefits) with these four data sets using the Weibull distribution. The probability that the value of net benefits falls below zero is also shown. Both mean and median values are presented to provide information on the degree of skewedness of the final net benefit distributions. The graphical representation of the distributions is found in figure 1.

Set I, $P(H)$ and $P(L) = 0$, is equivalent to the triangular distribution and provides a basis of comparison for the effect of the probability changes in sets II, III, and IV. Set II provides a base estimate with the Weibull distribution assuming a low prob-

Table 1. Estimates of Spewrell Bluff Project Annual Benefits and Costs

Benefits or Costs Classification	Low	Most Likely	High	Probabilities: Set II Low	Set II High	Set III Low	Set III High	Set IV Low	Set IV High
	$ (in thousands)								
Benefits									
Flood control	847.6	1173.9	1485.3	.05	.05	.20	.05	.05	.05
Hydrolelectric power	5034.1	5922.5	6200.0[a]	.05	.05	.20	.05	.05	.05
Navigation	25.1	28.0	30.2	.05	.05	.20	.05	.05	.05
Recreation	4202.0	5372.0	7394.0[b]	.05	.05	.20	.05	.30	.05
Fish & wildlife	57.5	127.5	172.5	.05	.05	.20	.05	.05	.05
Area redevelopment	0.0	830.0	1315.0[b]	.05	.05	.20	.05	.05	.05
Costs									
Annual capital cost	5945.8	6578.0	7038.5	.05	.05	.05	.20	.05	.05
Operations and maintenance	1741.7	2049.0	2192.4	.05	.05	.05	.20	.05	.30

[a] This is adjusted upward from the Taylor and North figure that is identical with the most likely value. The estimating algorithm used in the Weibull program requires that the upper bound exceed the most likely value.
[b] These values were adjusted from the Taylor and North figures because of skew limitations in the Weibull program.

Measurement of Economic Uncertainty in Public Water Resource Development: An Extension

Lloyd J. Mercer and W. Douglas Morgan

Renewed interest in incorporating measures of uncertainty in public investment decisions is a welcome addition to applied benefit-cost analysis. Taylor and North's (T-N) recent effort in this *Journal* to incorporate the consideration of uncertainty in benefit-cost analysis follows a technique that we have endorsed for some time (Mercer and Morgan 1975a, b, and 1976; Stacy and Buxbaum). This paper logically follows T-N by illustrating a more general procedure and demonstrates that inclusion of uncertainty in benefit-cost analysis need not be limited to the triangular distribution. The probability distribution used here is the Weibull. The major advantage of the Weibull distribution is its generality. It does not depend on fixed (absolute) estimates of endpoints (range) and thus offers increased capability to test for sensitivity to uncertainty. Use of the Weibull distribution is illustrated here by application to the Spewrell Bluff project and comparison of the results to those of T-N.

The Weibull Probability Distribution

The Weibull probability distribution is particularly well suited to incorporate efficiently subjective information (see Derman, Glesser, Alkin, or Mercer and Morgan 1975a,-or Weibull, for more discussion of technical details of the function). In general, the Weibull family may be described as unimodal and distributed continuously over nonnegative numbers, with the right tail approaching zero asymptotically as the random variable approaches infinity. The information necessary for each input variable is: (*a*) the most likely value of the input, X_0; (*b*) the estimated low value for the input, X_1; (*c*) the probability that the actual input value might be lower than the estimated low value, $P_1(X < X_1) = P(L)$; (*d*) the estimated high value for the input, X_2; and (*e*) the probability that the actual input value might be higher than the estimated high value, $P_2(X > X_2) = P(H)$.

The most likely value of the input (X_0) is the "best" estimate of X_0, while items (*b*) and (*d*) represent range information available to researchers when associated sensitivity tests are conducted. These three pieces of information are the general data requirement of the triangular distribution. The new information necessary for the Weibull probability distribution is the two probabilities [items (*c*) and (*e*)] associated with the endpoints. If the endpoints selected are the "true" endpoints of the distribution, the probabilities can be set at zero and represent no additional information cost to the researcher. This would, in effect, produce the triangular distribution as a limiting case.

The Weibull distribution allows two kinds of sensitivity tests to examine the robustness of project evaluation estimates. If the endpoints for the input variables are "estimates" of the low and high values, as is virtually always the case, their associated probabilities can be varied to examine the effect of differing degrees of uncertainty. An alternative sensitivity test of the impact of uncertainty can be made by varying the endpoints of input variables while their associated probabilities remain fixed.

Input information for the Weibull distribution is combined by the required algorithm for the output measure specified, i.e., net benefits or benefit cost ratio, and Monte Carlo techniques are used to simulate the final output distribution. The outcome of this procedure is the mean, standard deviation, and minimum and maximum values of the output distribution. With the current softwear, the full Monte Carlo simulation of output frequencies is printed. From this, the median value and the probability that the actual value lies above or below some cutoff figure can be read from the table of output frequencies. A histogram is prepared from the output frequency listing and is printed both directly and after being processed by a standard smoothing routine. Of course, all the caveats concerning approximations from Monte Carlo aggregation should be kept in mind.

Case Analysis: The Spewrell Bluff Project

To illustrate the application of the Weibull distribution and to compare its output with that of the triangular distribution, the Spewrell Bluff Project is reanalyzed. T-N's three subjective estimates (most likely, optimistic, and pessimistic) obtained from interviews with knowledgable personnel are the basis for the comparisons. T-N obtained the endpoint estimates for the included variables, for example, flood control benefits, by explicitly asking a question such as, "What is the lowest (highest)

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Table 3. Economic Values for Backfat, Feed Efficiency, and Average Daily Gain in Dollars Per Market Hog

Farm	Trait	dg_h = Genetic Change	
		1σ	-1σ
I, IA	Backfat	−0.95	0.96
I, IA	Feed efficiency	−1.44	1.44
I	Average daily gain	0.09	−0.21
IA	Average daily gain	0.94	−1.02
II	Backfat	−0.77	0.81
II	Feed efficiency	−1.12	1.19
II	Average daily gain	0.08	−0.10

produce 100 pounds of market hog. Changing the c_js to reflect the $\pm$ 1 σ changes in *FE* yielded the results in table 3. Because of the way *FE* is measured, an increase in *FE* ratio means that more feed is needed per pound of gain. Hence, increasing *FE* reduced net income.

ADG was increased and decreased by 0.15 pound of gain per day fed. These changes will be referred to as $\pm$ 1 σ changes. Changing *ADG* by changing number of days that animals were fed changed labor and space needs and costs of fuel and power. After making appropriate changes in the c_j and a_{ij}, the EVals in table 3 were obtained. For Farm I, the increase in net income resulting from a 1 σ increase in *ADG* is only 40% of the decrease in net income resulting from a 1 σ decrease in *ADG*. The effect on net income of varying *ADG* (and thereby changing labor requirements per hog) was much greater for the farm with the smaller supply of labor (Farm IA) than for the other farms.

Measured in absolute value, *FE* had the largest EVal for all three farms, and *ADG* had by far the smallest EVal for Farms I and II, whereas *BF* and *ADG* had nearly the same EVals for Farm IA. And for each trait EVal was larger for Farm I than for Farm II.

EVals computed by the procedure proposed in this paper may vary among firms having different factor endowments, managerial capabilities, market outlets, or lists of products they are capable of producing. The procedure cannot be used if adoption of the new strain of livestock requires use of a fixed resource not now available to the firm, e.g., a specialized machine not now owned. But the method can be modified to handle such problems.

One reviewer has questioned an asymmetry in our treatment of the effect of dg_h upon number of animals. A genetic improvement may raise net income by making it possible to raise more animals. The numerator of the equation measures this effect upon net income, but the denominator is number of animals before the genetic improvement. Our definition of EVal, presented at the beginning of the second section of this paper, is "the amount by which maximum profit may be expected to increase for each unit of improvement in that trait in each animal." If this definition is made more explicit by adding after "in each animal" the expression "that would be raised if the improved livestock were adopted," then the denominator is wrong. The correct denominator is $n_{h0} + dn_{h0}/dg_h$. The value of dn_{h0}/dg_h can be derived from values of dx_{j0}/dg_h. These values can be determined by use of procedures for sensitivity analysis (e.g., Gass, pp. 139–40).

Other Microeconomic Applications

EVals can be used in answering the question about what animals should be selected. EVals can also be used in answering the question of what traits we should try to improve.

EVals can be used to determine the maximum price a firm can afford to pay for a new strain of plants or animals.

The procedure used in this paper to measure EVal can be used to predict microeconomic effects of any technical change whose adoption would change values of parameters in a linear program. For example, it could be used to predict the maximum prices firms could afford to pay for a new fertilizer or need feed additive or the effect of a new technique on profits, thereby predicting the probable rate of adoption of a new technique. Such predictions could be used by scientists and engineers in selecting new machines, strains of plants or animals, fertilizers or pesticides to develop next.

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Table 1. Phenotypic Measures of Market Hogs

	Market Weights (pounds)				
Trait	180	200	220	240	260
Backfat (inches)	1.3	1.38	1.46	1.54	1.62
Feed efficiency[a]	3.4143	3.4656	3.5222	3.5850	3.6545
Average daily gain[b]	1.5246	1.5804	1.6298	1.6728	1.7109

Source: *Life Cycle Swine Nutrition.* Iowa Cooperative Extension Service and Iowa Agriculture and Home Economics Experiment Station Pamphlet PM-489(rev.), August 1974.
[a] Pounds of feed per pound of gain.
[b] Pounds of gain per day.

vember, and February. Feeder pigs can be purchased in June, September, December, or March. Pigs can be fed to weights of 180, 200, 220, 240, or 260 pounds. Females that farrow can be purchased or raised on the farm. The farm's fixed resources are central farrowing facilities, growing-finishing units, monthly family labor, and number of boars. The farm has a central farrowing house that is fully insulated and environmentally controlled and that has a 25-sow capacity. It has partial confinement growing-finishing units sufficient to house 250 head of 220-pound market hogs during the summer and has two boars.

The firm's purchased inputs are: all feed and feed additives, veterinary and medical expenses, fuel and power, feeder pigs and breeding stock purchased, and transportation of animals purchased or sold. Input-output coefficients were based on experience of typical midwestern swine operations and recommendations of the Iowa Experiment Station and Cooperative Extension Service. Characteristics of hogs grown are summarized in table 1.

Farm IA

The only difference between Farms I and IA is that Farm IA had 140 hours of family labor available monthly in October, November, April, May, and June, whereas Farm I had 160 hours.

Farm II

The differences between Farms I and II are these: Farm I can farrow four times and has two boars. Farm II can farrow twice and has one boar. Farm I has a central farrowing house. Farm II uses a pasture farrowing system.

Results

Table 2 shows number of hundredweights of market hogs produced in the basic optimal feasible solutions for Farms I, IA, and II. The solutions also called for purchasing feeder pigs and for selling cull gilts and sows. *BF* was assumed to increase and decrease by 0.15 inch. These changes will be referred to as $\pm$ 1 σ changes because 0.15 inch is one standard deviation. The only parameters of the linear program affected by changing *BF* are selling prices for market hogs. Making appropriate changes in the c_js to reflect $\pm$ 1 σ changes in *BF* yielded the EVals in table 3. These EVals are in terms of dollars per slaughter hog marketed. A 1 σ decrease in backfat increased net income of Farm I by 96¢ per slaughter hog marketed and increased net income of Farm II by 81¢ per slaughter hog marketed.

FE is measured as (number of pounds of feed fed)/(number of pounds gained) for a fixed number of days fed. *ADG* is defined as (number of pounds gained)/(number of days fed). EVal of a trait is to be measured by varying only that trait. To permit varying *FE* and *ADG* independently, we changed pounds of feed fed to change *FE,* and we varied number of days animals were fed to change *ADG*. *FE* was assumed to increase and decrease by 0.15 pound of feed per pound of gain. There are $\pm$ 1 σ changes in *FE*. The only parameters of the linear program affected by changing *FE* were the coefficients that measure quantities of feed fed to

Table 2. Levels of Marketings of Slaughter Hogs in Basic Optimal Feasible Solutions

	Market Hogs Farrowed						
	April	April	May	August	October	November	February
Farm	200[a]	260	220	260	200	200	260
	amount marketed (cwt.)						
I	—	—	590	697	—	387	598
IA	—	—	590	603	—	360	598
II	169	238	—	—	387	—	—

[a] Market weight.

equipment, etc. Figuring \$.03 per pig per day for labor, \$.002 per day for insurance, and \$.003 per day for maintenance of equipment, we have \$.035 per pig per day. Pigs which gained 1.6 lbs. per day instead of 1.5 would get to market 8 days sooner. On this basis, growth rate is worth 8 × \$.035 = \$.28 for each 1/10 lb. gain per day . . ." (p. 3).

Another method is the "gross-revenue" method. In applying this method, it is assumed that the only effect of the genetic change is on the price of the final product. This was used by Hazel (1956) for EVals of slaughter grade and twin lambs and by Arboleda, Harris, and Nordskog to find EVals for traits of laying chickens. A third method is multiple regression, in which net income is the dependent variable and measures of traits are independent variables. Nordskog applied this method to laying hens.

Two features shared by all three of these methods are simplicity and absence of insights into firm behavior that economics can provide. For examples: *(a)* The first two assume that the firm has only one optimal weight and grade of product and one optimal production process, and further assumes that the optimal weight, grade, and process are unaffected by the genetic change. *(b)* The first method (and also the third, if net income is income over all costs) assumes average fixed cost to be constant, i.e., the optimal number of animals is known and is unchanged by the genetic change. *(c)* None of the methods takes explicit account of the fact that EVals for one class of livestock can be influenced by genetic changes in other livestock products, or by changes in selling prices of other products or by changes in prices of inputs used in other products.[1]

The problem of measuring EVal is one that has been around for many years. The method applied to the problem in this paper is sensitivity analysis of linear programs. This tool also has been around for many years. What is new in this paper is neither the problem nor the tool, but the application of the tool of sensitivity analysis to the problem of measuring EVal. Applying this old tool to an old problem provides new information. What is done in this paper is analagous to what was done in papers by Westgren and Schrader and by Ladd. Evaluation of official grades for grain is a problem that has been with us for several decades. Ladd showed how application of sensitivity analysis to a blending problem of Westgren and Schrader could be used in evaluation of grain grades.

A Linear Programming Model for Measuring Economic Value

Our definition of economic value is: the amount by which maximum profit may be expected to increase for each unit of improvement in that trait in each animal. To develop a measure, we formulate a linear programming statement of a farm's profit-maximizing problem. Then we ask, what happens to the maximum level of profit when some parameters of the linear program change in response to a change in genetic composition of livestock? In answering this question, no input price is allowed to change, even though the livestock that undergoes change may be purchased.

Assume the traits of all biological inputs (e.g., feeder cattle and soybean seeds) and outputs (e.g., fed cattle and soybeans) of a farm are known, prices are known, and the farm's profit-maximizing problem can be written as a linear program in which x_j is the level of the jth farm activity, c_j is net revenue per unit of the jth activity, a_{i0} is total amount of ith fixed resource available to the farm, a_{ij} is amount of ith fixed resource used in production of one unit of output by activity j, and Z is total profit. Suppose also the farmer's profit-maximization problem has been formulated and solved as a linear program. Let Z_0 and x_{j0} be the optimal solution values of Z and x_j.

What would happen to the maximum value of net income if a genetically superior strain of livestock were to become available and were to be adopted on this farm? Suppose that the genetic value of the trait that is changed is g_h and that it is changed by the amount dg_h. Now $Z_0 \equiv \sum_j c_j x_{j0}$, and it is necessary to determine dZ_0/dg_h. Z_0 can be treated as a function of the c_j, a_{ij}, and a_{i0}. The change in g_h will affect some of the c_j and a_{ij} because changing genetic composition of livestock will affect some input-output coefficients or some product prices. The change in g_h will not affect any of the a_{i0}. The c_j and a_{ij} can be expressed as functions of the implicit parameter g_h, and dZ_0/dg_h can be evaluated by a procedure presented by Gass (pp. 139–140). To obtain EVal of the hth trait, it is necessary to divide dZ_0/dg_h by the number of animals produced of the species of livestock undergoing genetic change. Let this number be n_{h0}. Then, the economic value of the hth trait is $\text{EVal}_h = (dZ_0/dg_h)/n_{h0}$.

Application to Hogs

The procedure outlined in the previous section was used to measure EVals of three heritable characteristics in swine: backfat *(BF)*, feed efficiency *(FE)*, and average daily gain *(ADG)*. Results for three production conditions are sumamrized here.[2]

The analysis covered the 22-month period from 1 November 1972 through August 1974. This allowed for two complete cycles of breeding, gestation, feeding, and marketing. Prices of outputs and variable inputs used in the analysis were monthly Iowa prices during this period.

Farm I

Farm I may farrow its own pigs, buy feeder pigs, or do both. Farrowing times are May, August, No-

[1] Further discussion of EVals and their use in breeding can be found in seminal papers by Smith and by Hazel (1943). A good reference is Henderson. Arboleda, Harris, and Nordskog (1976a, 1976b) provide a convenient summary and an application.

[2] This section is taken from a thesis by Gibson.

Notes

Microeconomics of Technical Change: What's a Better Animal Worth?

George W. Ladd and Craig Gibson

In their review of research on technical change in agriculture, Peterson and Hayami cite 163 studies. Of the cited studies that present empirical results, virtually all deal with such questions as: *(a)* What technical changes have occurred? *(b)* What have been their effects? *(c)* What forces account for economic growth that has occurred? Also, virtually all of these studies are aggregative. They consider such variables as total expenditures on education, total public expenditures on poultry research, total stock of fixed capital. Study of such retrospective and aggregative questions can help us understand the past and influence the future.

But economists can do more to affect future technical changes. In each study cited by Peterson and Hayami, the economist came along after the "technical-change-makers" had done their work, and the economist made his measurements of past effects of changes that had already been made. Economists could work with technical-change-makers to influence the choice of technical changes that will be made in future.

An excellent example is the Taylor, Kohler, Maddy, and Enochian interdisciplinary study using parametric linear programming to determine the value of dehydrated alfalfa meal (dehy) in poultry feeds. They report that "parametric linear programming can help scientists evaluate the potentials of other research such as investigations of methods of altering the content of an ingredient. As an example, tests showed that a 40-percent increase in the metabolizable energy content of dehy would increase its value by $10.80 per ton, whereas the same percentage increase in lysine content would increase its value by only $2 a ton" (p. iv). Further, "Physical scientists in the Western [Utilization Research and Development] Division, at Albany, California, are presently evaluating these results as a guide to their research on dehy" (p. 14).

In this same study (Taylor et al.), agricultural economists cooperated with other agricultural scientists to measure some effects of possible technical changes—increasing metabolizable energy content and lysine content of dehy. These results were then used to guide future research of physical scientists.

The present paper reports an interdisciplinary effort by economists and animal breeders to develop measures that animal breeders can use to guide future work in livestock improvement.

Problem Statement

Animal and plant breeders, when selecting animals or seeds to use in breed improvement programs, are regularly faced with a number of questions: What is a better animal (or seed) worth? What makes one animal (or seed) worth more than another? What genetic changes should we make in the future? Answering the questions is complicated by two facts: a strain of animals or seeds superior in some of the traits that it will pass on to its offspring may be inferior in other traits; and because some pairs of traits have negative genetic correlations, breeding to improve one trait may degrade another trait. The breeder needs to make trade-offs. How much can he afford to degrade one trait while improving another?

Forty years ago, Smith introduced the selection index into plant breeding as a device for selecting plants and traits for seed improvement programs. Thirty-five years ago, Hazel (1943) introduced it into animal breeding. To compute a selection index, a breeder needs measures of economic values (EVals) of traits. Economic value of a trait has been defined as "the amount by which net profit may be expected to increase for each unit of improvement in that trait" (Hazel 1943, p. 2). Although breeders have measured and used EVals for some thirty-five years, they have yet to receive help from economists in developing economically sound methods for measurement. This paper reports an interdisciplinary effort to develop procedures for measuring EVals and presents one procedure and an application.

Before presenting an economic model for measuring EVals, some methods commonly used by animal breeders will be summarized. One method might be termed a "cost-budgeting approach." When Hazel (1956) applied this method to swine, he wrote: "The value of growth rate is a function of labor cost, insurance, maintenance of

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novative public policy approaches is needed on the price, income, and food problems to which the 1977 Act is a current response. Such studies would permit policymakers, as the termination date of the 1977 Act approaches, to have even more versatile, relevant, and accurate knowledge on which to base the public policy decisions that lie ahead.[8] Since it appears unlikely in the foreseeable future for us to perceive dependably whether the future forebodes plenty or scarcity, the research challenge is to devise policies both flexible and useful enough to serve the public interest under either scenario. In the absence of such research product within three years, the research establishment will have provided future policymakers no additional policy approaches or instruments and it can expect to find little sympathy for its oft repeated complaint that it is the same old policy with only slight rearrangement.

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[8] In his recent Fellows Address, J. Carroll Bottum argued, "Our challenge, as economists, is to develop alternative institutions which allow the producing segments of the economy to perform reasonably, efficiently, and effectively by society's standards" (p 766).

off-farm income marginally enhanced by the released labor of the set-aside program. The distribution of income will be left relatively undisturbed, with the larger and wealthier producers receiving their share of the benefits proportional to the income already controlled.

Alternatives. If the increase in farm output exceeds the assumptions or if net exports are less, the positive effects of the Act on producer prices and incomes will be even greater. On the other hand, if farm output lags behind or if net exports surpass the assumptions, then the range of price levels and incomes will move above those triggering any intervention by the Act, similar to the circumstances during most of the life of the 1973 Act. In that sense, the effects of the 1977 Act and of no policy would be indistinguishable. However, the upper peaks of both farm prices and income would be slightly blunted by the effect of the small reserves as they would be released for both domestic and export use.

Trade

Both commercial exports and imports will be slightly reduced by the strengthened prices—and controlled production—of the 1977 Act, compared to policy. Of course, some foreign markets are relatively insensitive to minor price changes and some are sensitive to unrestrained sales and price competition. Exports to weaker markets that depend on concessional sales or aid will be higher because of the aid and the reserves, compared to no policy. Furthermore, the regular foreign customer will experience some supply security in the presence of modest reserves and the "embargo-restraint" provision, and may respond with a margin of higher volume and stability of purchases. A finalized International Wheat Accord with prices and quantity bands could neutralize these trade expectations.

Alternatives. If the farm output exceeds the assumption or if exports are more sluggish than expected, the negative influence on trade under the 1977 Act will be magnified. If, on the other hand, the farm output lags substantially or if serious world shortages develop, exports and foreign food aid will be increased slightly by the modest reserves, and, of course, in proportion to their initial size.

Treasury Exposure

Treasury transfers to both producers and aid recipients, domestic and foreign, will be substantial compared to their essential absence under a no-policy situation. This takes no account of secondary effects or substitute kinds of transfers that might develop with a no-policy scenario. The transfers associated with the 1977 Act, with an admittedly large variance in prediction, will include a likely annual range of $1 to $1.5 billion at the outset and $2.5 to $3.5 billion toward the end of the period for direct producer deficiency and disaster payments; a relatively flat $5.5 to $6.2 billion for domestic food aid; $1.5 to $2 billion for foreign food aid; and additional administrative nonrecoverable loan and service costs for these programs and the reserves. Rapidly changing events already hint at the conservative nature of these estimates. The producer-payment portion of the treasury costs as a percentage of total federal outlays should not exceed those of the fifteen years prior to 1975 (U.S. Congress. Budget Office. Staff Working Paper).

Alternatives. If the farm output exceeds the assumptions or if exports lag, these costs will escalate rapidly. If the opposite happens, though, the producer transfers and substantial administrative costs would disappear while pressure could rise to increase food aid outlays.

Research Implications

Three challenges to policy research emerge from this critique of the 1977 Food and Agriculture Act.

First, continued improvement is needed in the information-gathering, analyzing, and reporting system relative to the multitude of variables that lend intelligence to policymaking and implementing in this price and income area. Particularly critical is the fact that the unfolding economic events must be captured quickly at the margin in either useful incremental measurements or projection models in order to assess rapidly comparative changes over time and between economic sectors.

Second, investigation is needed immediately on the extensive economic impact of the 1977 Act, with careful attention to alternate sets of assumptions about future national and international developments. Interrelations between the provisions and the general economy, income distribution, price and income stability, the organization and structure of agriculture, agricultural productivity, and the various subsectors of the food and fiber system are priority questions.

Third, continuing study of alternate and in-

unique 1972–74 period; (*f*) other demand trends and shifts continuing at about the same rate as in the recent past.

Thus, aggregate supply and demand for domestic agriculture would be approximately in balance, with a slight degree of effective production control operating most of the time. It is clear that the direction and rate of change in farm output and in net exports are the significant balancing factors—and unknowns—in the near future.

Using these general assumptions and applying conventional economic supply-demand analysis, we pose the question: What consequences might be expected in the approximate five-year life of the 1977 Act, compared to a like period in the future with no policy? A no-policy future may be defined as the absence of meaningful public price and income policy for the agricultural and food sector. That would mean the elimination of public food distribution at home and abroad, except for disaster relief, and no commodity price supports, production controls, reserves, deficiency or disaster payments, or agricultural export and import provisions. What would remain would be the general thrust of public agricultural developmental policies, such as land and conservation, research and education, credit, marketing institutions, food quality, and rural development.

Recognizing the possibilities of numerous important deviations from these base assumptions due to inherently unstable factors, largely foreign, which could produce major shocks in the system and hence significantly alter the projected consequences, two alternate assumptions are examined following each set of consequences. These alternatives are: (*a*) substantially higher growth in farm output or lower net exports, which could be associated with weather or policies of other governments; (*b*) substantially slower growth in farm output or higher net exports associated with the same unstable forces.

Consumers

Adequate food supplies will be available at price-level trends slightly lower than general consumer prices. The proportion of consumer income spent for food will gradually decline, but both of these trends will be slightly higher than with no policy. This difference arises from the production control-price support feature as well as the associated import restrictions. Low income consumers receiving substantive food subsidization will fare better with the food aid than with no policy. Finally, a national grain reserve, modest indeed, will provide consumers with a small degree of stability in food prices and the supply of food.

Alternatives. If the growth of farm output exceeds the assumption, or if net exports fall short, then the price-level disadvantages of the policy to consumers are magnified. The advantages of the food aid and the reserves would also be diluted. If the growth in output is less than the assumed pattern or if the net exports exceed the assumptions, due perhaps to world food shortages, adverse effects on consumers generally will be cushioned slightly by the policy, and low income consumers would gain even more.

Producers

Farm product prices will probably exhibit their traditional variability, not unlike the relative levels in the 1960s, but the lower boundaries will be somewhat higher than the outcome with no policy. The minimal price-support floors, the food aid programs, and production controls in most years will buoy up the lower price edge. Livestock prices will be similarly supported through the braking effect of the combined supply control and price support policy on feed supplies, which through the strengthened input price will restrain livestock numbers in the expansion phase of the cycle.

The considerable flexibility built into the production control features will permit shifts of resources as producers search for economic gains, but the mechanics of these allocative decisions will be somewhat restricted compared to the situation with no policy. This will result in the idling of some resources and an upward tendency on the real costs of production accompanied by downward pressure on productivity. On the other hand, the added stability of the policy will have a slightly positive effect on investment decisions by producers and the value of the farm asset structure.

Similarly, income levels for farmers will continue to vary, but with the lower boundary likely to be in the range of 70% to 80% compared to nonfarm incomes, somewhat higher than with no policy. This slightly raised income floor will be the result of the price-supporting activities, the significant flow of Treasury transfers, and the continued growth of

Table 3. Causes of Price Increases by Major Categories: 1973

Category	(1) Domestic Price & Income Effects	(2) Feed Costs	(3) Price Freeze	(4) Lagged Prices	(5) Error	(6) Actual
Beef (37%)	11.0	9.8	2.3	1.0	4.2	19.9
Pork (16%)	14.3	8.0	.4	11.0	−.7	33.0
Broilers (10%)	17.4	26.9	0.0	1.8	−1.7	44.4
Eggs (7%)	10.9	21.4	0.0	2.1	14.3	48.7
Dairy products (30%)	.03	9.6	0.0	−2.2	1.8	9.2
All livestock products	8.9	12.0	.9	1.8	−.3	23.3

pricing policies), and, to a much lesser extent, the devaluation and the Price Freeze II. However, the effects of that freeze and other government control during the whole 1972–74 period may have been much greater than the analysis here shows. The complete tracing-through of the effects of price controls is an enormous task by itself, and our treatment of that effect certainly has its shortcomings.

Concluding Comments

The results suggest that a main part of the food price inflation was caused by actions of governments, both U.S. and foreign. Monetary and fiscal policies implemented in 1972 were aimed at increasing the rate of economic recovery and reducing the rate of unemployment. The administration believed that price controls would permit more of the expansion to take place in real terms, and that such controls would restore the confidence of foreign governments in domestic policies to control inflation, and thus the stability of the dollar. In 1972, the Secretary of Agriculture was given the mandate to raise farm income, a goal seemingly consistent with the negotiation of increased foreign sales and the devaluation of the dollar. The apparent thinking was that increased agricultural exports would contribute positively to the balance of payments and offset any increasing capital outflows associated with lower domestic interest rates stemming from the expansionary monetary policy. Had worldwide food consumption and production been on a more balanced course, the inconsistencies in these policies might not have emerged so abruptly or to the extent they did. But, given the information at hand, the potential inconsistencies should have been evaluated more fully, and the small margin for error more fully appreciated.

The Russian grain deal came at a time when inconsistencies among various targets were about to surface. The first devaluation of the dollar, combined with rising world income growth, was already spurring export demand.

Table 4. Decomposition of All Livestock Product Price Increases by Major Causes: 1973

Category	(1) Domestic Price and Income (Y and PAO)	(2) Government Policy	(3) Other Supply Factors	(4) Devaluation	(5) Russian Grain Deal
All livestock products (retail)	8.9	4.4	−3.7	1.2	3.4
Percent distribution	38.4	18.9	−16.9	5.1	14.6

Category	(6) World Demand Factors	(7) World Supply Factors	(8) Price Freeze II	(9) Error	(10) Actual
All livestock products (retail)	1.9	2.4	0.9	3.7	23.2
Percent distribution	8.2	10.3	3.9	15.9	100.0

Under these conditions, 1972 policies with respect to acreage restrictions proved inappropriate, especially in face of trends in worldwide production and stock positions. Domestic and world income growth put substantial pressure on the demand for meats and feed grains. Given these circumstances, the transaction with the Soviets set off a chain of events in world grain markets which led to explosive price increases in grains and other feeds. The course of price expectations for both grain and livestock producers was radically altered in response to the changed grain supply-demand conditions, and this led to production adjustments in the livestock sector that precipitated the shortage situation in meats.

When price controls were first implemented, it was not intended that they would have to cope in any significant way with fundamental food price inflation.[5] However, once the inflation in grain and meat prices manifested itself, the inconsistency between overall economic activity and income growth, and control over the price level became acute. The inconsistencies of the policies then found the government fighting a rear guard action on the inflation front, each action precipitating further reactionary moves, some with international repercussions. Such reversals in policy no doubt damaged the credibility of U.S. commitments to free trade policies, with whatever long-run costs this may entail. None of the minor reversals in policies in 1973 and 1974 effectively served to offset the effects of basic errors in policy made earlier. If anything, these reactionary moves served to further upset expectations and production decisions within the livestock-feedgrains economy.

What we have tried to accomplish here is not to arrive at a definitive set of numbers, but rather to present a line of reasoning. We used, as an engine of analysis, a set of econometric models whose coefficients are known with a reasonable degree of statistical precision. The models served both as guides through a bewildering set of events and as instruments for maintaining consistency between exogenous events and their associated economic outcomes. If the relations between the events and their outcomes are essentially correct, and we believe that they are, then there are several lessons to be drawn from the experience of that period. The integration of food policy with macro-economic and international trade policy leaves considerable room for improvement. In circumstances where economies undergo major adjustments to fundamental economic variables, such as currency devaluation, it is questionable for governments to pursue policies which have potentially large and unknown consequences for marketplace adjustments. Where worldwide market conditions dictate price adjustments, individual governments are ill-advised to pursue price control policies aimed at insulating their consumers from needed price adjustments.

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[5] Although the precise motivation may never be known, there is considerable evidence to indicate that international monetary policy was more responsible for price controls than concern over domestic price levels. See Government Printing Office, pp. 15–17.

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Appendix A

Federal Government Policy Actions to Increase Supply During Phases III and IV

Date	Action
Phase III	
1973	
January 11	Direct subsidies ended on remaining farm product exports (applying to chickens, flour, and lard).
	Mandatory wheat acreage set-asides suspended for 1973 crop.
	Additional grain to be sold from CCC stocks before 30 April, totaling 278 million bushels of wheat and 200 million bushels of feed grains.
	Loans terminated on farm-stored grain.
	Livestock grazing permitted on set-aside acreage.
January 31	Feed grain acreage set-asides reduced for 1973 crop.
March 8	Dairy price supports increased to mandatory minimums.
March 26	Feed grain acreage further reduced; haying permitted on set-aside acreages.
April 5	Interagency Task Force established to coordinate grain transportation policies.
April 6	Suspension of exports of vegetable oils under CCC Export Credit Sales Program and the Barter Program. Reduction in P.L. 480 exports of edible oils under Titles I and II of that Act.
April 19	Rice acreage allotments increased for 1973 crop.
April 25	Cheese import quotas increased (approximately 64 million lbs.).
May 10	Import quotas increased on nonfat dry milk (approximately 60 million lbs.).
Phase IV	
1973	
July 19	Wheat and feed grain set-asides suspended for 1974 crops.
July 27	Export embargo replaced by validated export licensing system.
August 10	Agriculture and Consumer Protection Act of 1973, establishing a target price system to support farm incomes; export monitoring made a part of the Act.
August 28	Import quotas increased further for nonfat dry milk (by about 100 million lbs.).
August 29	Price support level for soybeans held at \$2.25/bu. for 1974 crops.
September 21	Export controls on oilseed products lifted, effective 1 October.
October 3	Agricultural production and food processing given higher priority in propane gas allocation program.
October 25	Fertilizer price decontrolled by CLC; export monitoring system established.
November 1	Butter import quotas increased (by 56 million lbs.).
November 27	Sugar import quotas increased.
December 20	Loans on 1973 wheat crop called for 15 January 1974 delivery.
December 28	Feed grain manufacturers released from Phase IV controls.

Date	Action
1974	
January 2	Chedder cheese import quotas temporarily increased (approximately 100 million lbs.). Rendering industry released from controls.
March 4	Import quotas again increased for nonfat dry milk (by 150 million lbs.).
June 13	Announce weekly export monitoring system for oilseed products.
June 27	Temporary export embargo on oilseed products.
July 5	Temporary export restriction extended to 41 categories of agricultural commodities, including edible oils, animal fats, and livestock protein feed.
July 18	Import quotas again increased for nonfat dry milk (by about 80 million lbs.).
August 26	Elimination of set-aside requirements on 1975 crops for wheat, feed grain, and upland cotton.

Sources: Phase III, *1974 Economic Report of the President*, p. 95; *Quarterly Reports* (1973–74), Cost of Living Council; various USDA *Situation Reports* for wheat, feed grains, and dairy products. Phase IV, *1974 Economic Report of the President, p. 95; Quarterly Reports* (1973–74), Cost of Living Council; and various USDA *Situation Reports* for wheat, feed grains, and dairy products.

Appendix B

List of Variables

AUX — Animal units in the EEC-6, UK and Japan (mil. animals)
CPBSE — Corn production plus beginning stocks in EEC-6 (mil. bu.)
CPBSP — Corn production plus beginning stocks in principal exporting countries: Argentina, South Africa, and Thailand (mil. bu.)
DD — U.S. dock strikes dummy
DEV — Devaluation effect measured as percent change in U.S. exchange rate
DU — Average import levy in Netherlands for corn ($/bu.)
EC — U.S. corn commercial exports (excludes USSR) (mil. bu.)
FEUC — U.S. feed use of corn (mil. bu.)
IX — Income in EEC and UK (index)
LSN — Livestock numbers in the U.S. (mil. animals)
OMF — World minus U.S. exports of oilseed meal (mil. lbs.)
PAO — Price of all nondurables and services except beef, pork, and poultry (index)
PC — Season average price of corn ($/bu.)
PCENDS — Personal consumption expenditures on nondurables and services (bil. dollars)
PLX — Livestock prices in the EEC and UK (index)
PSM — Price of soybean meal ($/ton)
QMD — Domestic soybean meal demand (mil. lbs.)
QMP — Quantity of soybean meal produced (mil. lbs.)
QMX — U.S. exports of soybean meal (mil. lbs.)
T — Time trend, 1950 = 1.0, . . .,
WLSP — Weighted livestock price ($/cwt.)
WRMP — Wage rate meat processing ($/hr.)
ZG — Trend growth for meal demand (index)

Factor Intensities and Locational Linkages of Rural Consumption Patterns in Sierra Leone

Robert P. King and Derek Byerlee

An understanding of consumer behavior is important for the analysis of the effects of changes in income distribution on the development process. Factor intensities and locational linkages of consumption patterns at different income levels are estimated for rural households in Sierra Leone. Results lend support to the hypothesis that low income households consume goods and services requiring less capital and foreign exchange and more labor than do higher income households. At all income levels households allocate more than 75% of consumption expenditures to goods produced in rural areas. Rural consumption linkages with urban sectors, then, are not well developed.

Key words: Africa, consumption, factor intensity, locational impacts.

In recent years income distribution has become a central concern of researchers and planners working in developing countries. It is clear, however, that an understanding of income distribution in the development process requires a knowledge of how consumers in different income classes allocate expenditures. One widely accepted hypothesis that underlies much current thinking in economic development holds that lower income households consume products that require less of the scarce factors, capital and foreign exchange, and more of the abundant factor, labor. This hypothesized variation in factor intensities of consumption patterns is intuitively attractive to proponents of income redistribution toward the poor since such redistribution will result in consumption of more labor intensive commodities, which in turn increases employment and further promotes income equality. Moreover, there need be no trade-off between more equitable income distribution and growth since commodities consumed by low income households also use less of the scarce factors, capital and foreign exchange. This hypothesis was first explicitly stated in the International Labour Office report on Colombia, but it has been widely applied in theoretical analyses of the development process which espouse strategies for more equitable growth, e.g., Lewis.

There is little empirical evidence available to support this hypothesized relationship between income distribution and the factor intensity of consumption patterns despite its obvious importance in the design of development strategies. Results of studies conducted by Soligo in Pakistan and Sunman in Turkey do provide rather strong evidence that the consumption patterns of low income households in both of these countries are more labor intensive and less capital intensive. Simulation experiments conducted as part of both studies to determine the effect of alternative distributions of incremental incomes indicate that a more equitable income distribution does lead to greater increases in domestic value added and to more aggregate labor employment. In both Pakistan and Turkey, income distribution is highly skewed, even in rural areas, and socioeconomic differences among income classes are pronounced. In many African countries, on the other hand, income distribution in rural areas is more nearly uniform, and differences among classes are not as clearly defined. These are factors which may affect

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the strength of the consumption linkage between income distribution and the pattern of factor demand. To date, however, factor intensities of consumption patterns have not been estimated in any African country.

The impact of rural consumption expenditures on other sectors of the economy is a second important set of consumption linkages. These linkages—called locational linkages in this paper—can be defined in terms of three basic dichotomies: home-produced versus purchased goods, rurally produced versus urban produced goods, and domestically produced versus imported goods. The significance of these linkages arises out of attempts by development theorists to trace the multiplier effects of rural development strategies through the economy. For example, Mellor views food grain technologies as a major impetus for rural development and rural consumption expenditures as the primary means of translating these gains into other sectors of the economy. The most explicit theoretical treatment of these locational linkages is provided by the Hymer and Resnick model of an agrarian economy, in which the income elasticity of demand for rural nonagricultural activities is shown to be an important determinant of marketed surplus and the demand for urban produced goods. Again, little empirical evidence is available to analyze the locational linkages of consumption patterns. Indeed estimates of the income elasticity for rural nonagricultural goods are rarely available (Liedholm).

This paper aims to estimate empirically the relationship between income distribution and the factor intensity and locational linkages of consumption patterns. One important reason for the lack of empirical research in this area is the fact that consumer expenditure data are usually not collected in a form in which commodities produced by labor intensive techniques or in rural or urban areas can be distinguished. For the present analysis, a nationwide rural survey was designed and conducted in Sierra Leone specifically for analysis of these relationships. The following section briefly describes the survey methods employed and some characteristics of the data. These data are then used to estimate expenditure elasticities and marginal propensities to consume by income group, which are the basis for the analysis of factor intensities and locational linkages of the observed consumption patterns.

Survey Methods

This study is based on cross-sectional data collected in a national rural household budget survey of Sierra Leone conducted between March 1974 and May 1975. Expenditure data were collected for a highly disaggregated set of commodities. Information concerning the origin of purchased goods was also recorded.

The sample was selected by stratifying rural areas of Sierra Leone into eight resource regions, randomly selecting three census enumeration areas within each region and then randomly choosing about ten households in each enumeration area. The final sample size was 203 households.

Each household was visited by an enumerator resident in that enumeration area on a twice weekly basis throughout the survey year. Information on farm and nonfarm production was recorded on a daily basis as part of a related farm management survey. This information was used to estimate subsistence consumption by subtracting sales from total household production.

Cash consumption expenditures were recorded on two additional questionnaires. In the first questionnaire, expenditures on frequently consumed products—largely food items—were recorded in two interviews for eight consecutive days of each month. Expenditures on nonfood items were recorded at the end of each month for the preceding month in a second questionnaire. Because of substantial seasonal variation in cash expenditures, data for each household were collected over twelve consecutive months.

Enumerators were instructed to be as specific as possible about the nature of commodities in order to facilitate commodity groupings which reflect homogeneity with respect to factor intensities. The origin of each commodity was recorded in four categories: rural areas, small-urban areas (population 5,000–100,000), large-urban areas (population over 100,000), and foreign.

The sample of households was post stratified into six income classes. Following Kuznets (p. 87), these income classes were defined on the basis of per capita household expenditure rather than total household expenditures. The first and sixth income classes comprise, respectively, the lower and upper 10% of households ranked by per capita consumption expenditures. Income classes two through five are made up, respectively, of households in

the second and third, fourth and fifth, sixth and seventh, and eighth and ninth deciles of the ranked sample population.

Average annual per capita expenditure in the sample was 116 Leones per year, approximately $128 (U.S.). The estimated Gini ratio of income distribution for the sample is .32, which is quite low for developing countries. This rather uniform income distribution reflects the fact that in rural areas of Sierra Leone access to land is not severely constraining and most farmers use similar traditional technologies.

Food accounts for 70% of all consumer expenditures (subsistence and cash) in the sample. Rice is the staple food in Sierra Leone, comprising over half of all food expenditures. Other food items which make up over 5% of all expenditures are root crops, palm oil, and fish. The most important nonfood items recorded in the sample were fuel and light, cloth, household items, and ceremonial and service expenditures. As expected, because of the predominance of food expenditures, the subsistence ratio is high, averaging almost 50% of all expenditures in the sampled households.

Estimation of Marginal Propensities to Consume

The analysis of both the factor intensity and the locational linkages of consumption patterns is based on marginal propensities to consume estimated for individual commodity groups from the survey data. For the purpose of estimating factor intensities, commodities were grouped into fifteen categories corresponding to a sectoral disaggregation of the economy for which information on labor and capital use was available. Commodities were reclassified in terms of their origin for the analysis of locational linkages.

In specifying a model for the statistical estimation of marginal propensities to consume, several unique requirements of this study were considered. First, because marginal propensities were estimated for a diverse set of commodities, a model flexible enough to represent the income-consumption relationship for a wide range of commodities and at extreme levels of incomes was required. Second, a function's conformability with the criterion of additivity was also important. That is, marginal propensities to consume for all commodities should sum to unity, since commodity groupings used in this study are mutually exclusive and exhaustive. Perfect additivity at all income levels is also necessary for interclass comparisons of consumption patterns. Finally, problems caused by the presence of zero expenditure levels for certain commodities as well as important and more commonly recognized criteria, such as goodness of fit and the significance of parameter estimates, were considered in model specification.[1]

In light of these requirements, the ratio semi-log inverse function (RSLI) was chosen for the empirical analysis. It was initially specified in equation (1) for per capita consumption expenditures which were the basis for classifying households by income class,

$$(1) \quad \bar{c}_{ij}/\bar{y}_j = a_i + b_{1i} ln\bar{y}_j + b_{2i}/\bar{y}_j + u_{ij},$$

where $\bar{c}_{ij}$ is per capita total expenditure on commodity i by household j; $\bar{y}_j$ is per capita total consumption expenditure by household j; a_i, b_{1i}, and b_{2i} are parameters to be estimated for the ith commodity; and u_{ij} is a disturbance term. This functional form, first proposed by Leser, meets the additivity criterion exactly at all income levels and, at the same time, is flexible enough to allow increasing, decreasing, or constant marginal propensities to consume for a given commodity.[2] In addition, because the dependent variable is not specified in logarithmic form, the RSLI function is not as adversely affected by zero observations.

Implicit in any per capita income-consumption specification is the assumption that economies and diseconomies of scale with respect to household size do not exist. To permit greater flexibility with respect to household size, the model was transformed from a per capita form to one which represents consumption for the entire household. This is done by first multiplying both $\bar{c}_{ij}$ and $\bar{y}_j$ in the dependent variable by N_j, the number of people in household j, and introducing household size as an independent variable by multiplying both sides of the equation by Y_j, total consumption expenditure by household j. The result is

$$(2) \quad C_{ij} = a_i Y_j + b_{1i} Y_j ln\bar{y}_j + b_{2i} N_j + u_{ij},$$

where C_{ij} is total consumption expenditure on

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[1] See King and Byerlee for a discussion of the effect of zero observations on parameter estimates of a log-log inverse model.

[2] The MPC for commodity $i, \frac{\partial \bar{c}_i}{\partial \bar{y}} = a_i + b_{1i} + b_{1i} ln\bar{y}$, decreases monotonically when $b_{1i} < 0$, increases monotonically when $b_{1i} > 0$ and is constant when $b_{ii} = 0$ for all $\bar{y} > 1.0$.

good i by household j; a_i, b_{1i}, and b_{2i} are again parameters to be estimated; and other variables are defined as above.[3] The household size variable used in the analysis of expenditure patterns ideally should be adjusted for compositional factors pertaining to the age and sex of household members. Consumer equivalent scales based on a priori weights which approximate relative caloric requirements have been used in some African consumption studies, e.g., Howe and Massell. But, as Prais and Houthakker note, such scales should be commodity specific. Singh and Nagar have developed an iterative technique for estimating commodity-specific, consumer unit scales, but its use complicates estimation procedures considerably and results in a definition of the average consumer that may not be in accordance with that of policy makers and planners. This technique, then, was not used in the analysis which follows, and the household size independent variable is not adjusted for compositional factors.

In addition, the subsistence ratio was included as an independent variable in the analysis, because a household's pattern of consumption is related to its orientation toward the consumption of home-produced goods (Massell). Regional binary variables were also included in the model to reflect differences in taste, the availability of goods, and the prices of goods. Adding the subsistence ratio for household j, S_j, in logarithmic form and a set of regional binary variables, R_{hj} being 1 if household j is in region h and 0 otherwise, the model becomes

$$(3) \qquad C_{ij} = a_i Y_j + b_{1i} Y_j ln \bar{y}_j + b_{2i} N_j + b_{3i} ln S_j + \sum_{i=1}^{8} g_{hi} R_{jh} + u_{ij}.$$

Because as specified in equation (2) the function passes through the origin, all eight regional binary variables are included. Expressions for the marginal propensity to consume and total expenditure elasticity derived from this model are respectively:

$$(4) \qquad \frac{\partial C}{\partial Y} = a_i + b_{1i} + b_{1i} ln \bar{y}$$

[3] The first term on the right hand side of equation (2) establishes a linear relationship between consumption on the ith good and total consumption expenditure. As demonstrated by Prais and Houthakker, this insures that perfect additivity continues to hold.

and

$$(5) \qquad \frac{\partial C}{\partial Y} \cdot \frac{Y}{C} = (a_i + b_{1i} + b_{1i} ln \bar{y}) \frac{Y}{C}.$$

Parameters of this model were estimated using ordinary least-square (OLS) regression.

As noted by Summers, parameters estimated using OLS are biased and inconsistent when total consumption expenditure is used as a measure of income in estimating Engel curves. Massell has suggested the use of two-stage least-squares regression (TSLS) to deal with this problem. In order for its use to be valid, however, he is forced to assume that production and consumption decisions are independent (p. 138, n. 6)—a tenuous assumption when subsistence consumption represents a major portion of a household's total consumption expenditure. Therefore, the OLS model was considered adequate for this study.

Nevertheless, biases are likely to be introduced by the correlation of independent variables and the error term. These limit the validity of hypothesis tests concerning the magnitudes of individual parameters, and they may affect estimates of marginal propensities to consume and expenditure elasticities. In a comment to the Summers article, Prais shows that, for an additive function such as that used here, the expenditure elasticity of a given commodity will be biased toward unity and that the size of the bias will be larger the greater the budget share for the commodity in question. The marginal propensities to consume and expenditure elasticities presented here should, then, be interpreted with these facts in mind, particularly for commodities such as rice with large budget shares.

Finally, problems of heteroscedasticity and multicollinearity, which are common to nearly all budget studies, were given consideration. Estimation techniques more sophisticated than those employed in this study (e.g., weighted regression and ridge regression) have been developed to deal with these problems. Because neither problem caused obvious difficulties, however, expectations of increased accuracy did not warrant the use of these techniques. The particular strengths of this study—the accuracy of the survey data and conformity with the economically important additivity criterion—are likely to be more important factors in determining the validity of our results.

The Factor Intensity of Rural Consumption Patterns

The marginal factor intensity F_{jk} for factor j, is defined as the quantity of labor, capital, or foreign exchange required to produce goods embodied in a marginal unit of consumption expenditure at income level k. Symbolically, it can be defined in the following manner:

$$(6) \qquad F_{jk} = \sum_i \left(\frac{\partial C_i}{\partial Y}\right)Y_k \cdot \Delta f_{ij},$$

where $\partial C_i/\partial Y$ is the marginal propensity to consume good i at income level Y_k, and Δf_{ij} is the marginal requirement of factor j in producing a unit of good i. In the case of capital and labor, Δf_{ij} represents the sectoral capital-output and labor-output ratios. Average and marginal factor-output ratios were assumed to be equal—that is, increases in output are realized by employing production techniques of the same capital and labor intensity as currently exist. Capital-output and labor-output ratios used in this study are given in table 1. Both capital and labor requirements were measured in flow terms and derived from a variety of sources. Labor and capital requirements for the production of various agricultural commodities were calculated from survey data and from information given in Spencer and Byerlee's analysis of incomes and productivity in rural areas of Sierra Leone. Results from a nationwide industrial survey of Sierra Leone by Liedholm and Chuta were used to calculate labor-output and capital-output ratios for the large- and small-scale industrial sectors. Finally, data given in *The National Accounts of Sierra Leone, 1964/65 to 1970/71* were the basis for the determination of economic ratios for the transport and education sectors. The service and ceremonial and miscellaneous components of consumption expenditure, because they represent expenditures on goods from all sectors, were assumed within an income class to have labor-output and capital-output ratios equal to the average value of these ratios over all other sectors. Marginal foreign exchange requirements were set at unity for imports and zero for all other commodity groupings. Only direct foreign exchange requirements were considered. Foreign exchange embodied in capital equipment, for example, was not included in the analysis.

Parameter estimates and total expenditure elasticities for each commodity group are given in table 1. Significantly, the elasticities of labor-intensive sectors, such as agricultural products and services, are high. For the large-scale industry sector, which is relatively capital intensive, the elasticity is quite low and in fact less than for small-scale industry products, produced mostly by labor-intensive rural firms.

The significance levels of the two parameters used to compute total expenditure elasticities and marginal propensities to consume warrant a brief comment. Trial regressions using semi-log, log-log, and log-log inverse models yielded coefficients consistently more significant in a statistical sense. All of these models lead to serious problems, however, because they fail to meet the important economic criterion of additivity, especially at extreme levels of income. In addition, the existence of zero expenditure levels by some households on many commodities leads to serious statistical problems when parameters are estimated using the log-log or log-log inverse models, which have a logarithmic dependent variable (see Prais and Houthakker, pp. 50–51).

Marginal propensities to consume and marginal factor requirements for each income class are given in table 2. Marginal propensities to consume fall for most agricultural products, which are labor intensive, but they also fall for fish and large-scale industry products, both of which are more capital intensive. The marginal propensity to consume for the services and ceremonial category increases sharply across the range of incomes.

The labor requirements per Leone of expenditure at the margin fall as incomes increase, indicating that lower income groups consume a more labor intensive bundle of commodities. However, capital requirements also fall, which is the opposite of what is hypothesized. At the same time, foreign exchange requirements as measured by the marginal propensity to consume imported goods increase with income level. The fall in capital intensity at higher incomes can be explained by the fact that high income households, with their greater marginal propensity to consume imported products, substitute imported goods for capital-intensive domestically produced goods. Furthermore, since capital requirements are quite small relative to foreign exchange requirements, the total requirement for these two scarce factors increases over the

Table 1. Parameter Estimates and Total Expenditure Elasticities for Commodities Grouped by Sector

Commodity Group	Factor Ratios L/O[a]	Factor Ratios K/O[b]	Coefficient of Y	Coefficient of $Y\ln\bar{y}$	Coefficient of N	Coefficient of $\ln S$	R^2	Total Expenditure Elasticity[f]
Rice	12.75	.017[c]	.7899 (.336)[e]	−.0701 (.058)	−4.7213 (6.215)	44.7052 (12.320)	.676	.99
Cereals and root crops	16.56	.017[c]	.4407 (.183)	−.0636 (.032)	−4.7824 (3.402)	10.2637 (6.743)	.387	.82
Fruits and vegetables	9.89	.017[c]	.0882 (.062)	−.0121 (.011)	−.8334 (1.148)	5.9076 (2.276)	.296	.78
Palm oil	5.16	.017[c]	.1187 (.130)	−.0060 (.022)	0.5799 (2.401)	−11.9078 (4.760)	.399	1.08
Meat and livestock products	4.80	.017[c]	−.1854 (.053)	.0360 (.009)	3.1944 (.980)	1.3942 (1.943)	.247	1.37
Fish	5.30	.227	.2863 (.127)	−.0373 (.022)	−1.7032 (2.346)	−1.3201 (4.469)	.480	.81
Rural beverages and tobacco	10.79	.017[c]	−.0988 (.068)	.0185 (.012)	1.2376 (1.250)	6.1287 (2.477)	.164	.58
Small scale industry products	5.95	.178	.0243 (.045)	−.0005 (.008)	.0583 (.837)	−3.9583 (1.659)	.344	.76
Large scale industry products	.28	.267	.0600 (.042)	−.0077 (.007)	.9776 (.783)	−4.8290 (1.551)	.231	.33
Transport	1.16	.310	.0633 (.060)	.0163 (.010)	.5445 (1.111)	−6.4254 (2.202)	.281	1.38
Services and ceremonial	d	d	−.4985 (.112)	.1006 (.019)	7.4250 (2.081)	−6.2136 (4.124)	.455	2.38
Education	1.71	.026	−.0426 (.046)	.0085 (.008)	1.0444 (.852)	−4.6476 (1.690)	.150	.53
Osusu saving	0	0	.1123 (.090)	−.0180 (.016)	−1.9689 (1.671)	−1.8247 (3.313)	.072	.71
Miscellaneous	d	d	−.1331 (.094)	.0288 (.016)	1.7947 (1.740)	−5.5957 (3.449)	.157	2.09
Imported products	0	0	.1040 (.162)	.0065 (.028)	.2180 (2.995)	−21.7191 (5.937)	.518	1.07

[a] Person hours per Leone of output.
[b] Annual cost of capital per Leone of output.
[c] Capital-output ratios are identical for agricultural products because it was not possible to disaggregate capital use by crop. The costs of tree plantations, livestock herds, etc., which are the direct embodiment of labor, are not included in the determination of annual capital costs.
[d] Assumed to equal the average of capital output or labor-output ratios for all other domestic sectors, weighted by budget share.
[e] Figures in parentheses are standard errors. The probability level at which parameters are significantly different from 0 can be determined using a one-tailed t-test.
[f] Computed at the mean expenditure level.

range of incomes. The results, then, tend to support the hypothesis that low income households consume goods and services which require less capital and foreign exchange and more labor than do the goods embodied in the consumption patterns of higher income households.

The changes in factor intensities by income level are small relative to other studies. Marginal labor requirements decrease over the range of sample incomes by 23%, while capital requirements fall by 8% and foreign exchange requirements increase by 11%. In Pakistan, Soligo found an increase of 82% in marginal capital intensity and a decrease in marginal labor intensity of 56% over the range of incomes in rural areas. Sunman's results for Turkey show a 27% increase in capital requirements and a 49% decrease in labor requirements from the lowest to highest income group when a final consumption measure of output is used. To a large extent, the relative homogeneity of consumption patterns in rural Sierra Leone can be attributed to the comparative uniformity of the income distribution. Moreover the capital intensity of consumption patterns in Pakistan and Turkey at all income levels is appreciably higher than in Sierra Leone, indicating the predominance of small-scale agricultural, fishing, and industrial sectors, as well as imports, in providing consumer goods to the Sierra Leone rural population.

Table 2. Marginal Propensities to Consume and Marginal Factor Requirements by Income Class

	Marginal Propensity to Consume						
		Income Class					
Commodity Group	Mean Expenditure Level	Lowest Decile	Second and Third Deciles	Fourth and Fifth Deciles	Sixth and Seventh Deciles	Eighth and Ninth Deciles	Highest Decile
Rice	.386	.473	.438	.405	.383	.359	.328
Cereals and root crops	.074	.153	.121	.091	.071	.049	.022
Fruits and vegetables	.018	.033	.027	.022	.018	.013	.008
Palm oil	.084	.092	.089	.086	.084	.082	.079
Meat and livestock products	.022	−.023	−.004	.012	.024	.036	.052
Fish	.071	.118	.099	.081	.070	.057	.041
Rural beverages and tobacco	.008	−.015	−.006	.003	.009	.015	.023
Small scale industry products	.021	.022	.022	.021	.021	.021	.021
Large scale industry products	.016	.025	.021	.017	.015	.013	.009
Transport	.030	.010	.018	.026	.031	.037	.044
Services and ceremonial	.081	−.044	.006	.054	.085	.120	.163
Education	.006	−.004	—	.004	.006	.009	.013
Osusu saving	.009	.030	.022	.013	.007	.002	−.006
Miscellaneous	.033	−.003	.010	.025	.034	.043	.056
Imported products	.141	.133	.137	.140	.142	.144	.147
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000
	Marginal Factor Requirements						
Labor requirements (person hours)	8.36	9.40	9.06	8.65	8.31	7.87	7.25
Capital requirements (Leones)	.049	.050	.050	.049	.049	.048	.046

Locational Linkages

Commodities were reclassified in terms of their origin, to analyze the strength of locational linkages of expenditure patterns at different income levels. Recall that five categories are used: subsistence, rural nonsubsistence, small-urban, large-urban, and imported. Parameter estimates and total expenditure elasticities for these commodity categories are given in table 3. Elasticities for rurally produced products and for imports are both close to unity, 1.00 and 1.07, respectively. The elasticity for small-urban products is surprisingly high, while that for large-urban products—mostly kerosene refined in the capital city—is quite low. Within rurally produced commodities, the elasticity for rural nonfood products is 1.40. This subcategory represents expenditures on rural nonfarm products marketed within rural areas, which Hymer and Resnick have hypothesized to be inferior. In contrast, our results show that these actually have an elasticity well above unity in Sierra Leone.

Marginal propensities to consume for commodities grouped by origin are given in table 4. Turning first to the allocation of consumption expenditures between home-produced and purchased goods, it is clear that the marginal propensity to consume subsistence goods drops dramatically as incomes increase. Almost 70% of increased expenditure is allocated to subsistence food consumption by households at the lowest income level, while the subsistence proportion falls to 29% at the highest income level. To some extent, this decline is due to a decreasing marginal expenditure for food as incomes rise, but there is also a switch from subsistence produced food to food purchased in the market.

Marginal propensities to consume all rural products in table 4 clearly demonstrate the predominance of rural produced goods in the expenditure patterns of rural consumers at all income levels. The marginal propensity to consume rurally produced goods falls only slightly as incomes rise, and even households in the highest income group allocate more than 75% of total consumption expenditure at the margin to these goods. Although market orientation does increase as incomes rise, very little of this increased market activity extends out of the local rural economy. Rather, as incomes rise increased cash purchases are directed toward rural nonfood products, particularly service and ceremonial expenditures.

Marginal propensities to consume products

Table 3. Parameter Estimates and Total Expenditure Elasticities for Commodities Grouped by Origin

Origin Classification	Coefficient of Y	Coefficient of $Y\ln\bar{y}$	Coefficient of N	Coefficient of $\ln S$	R^2	Total Expenditure Elasticity[b]
Rural subsistence food products	1.5556	−.1930	−11.9226	108.2474	.819	.87
	(.307)[a]	(.053)	(5.685)	(11.270)		
Rural purchased food products	−.0758	.0506	3.3676	−52.5338	.728	1.06
	(.207)	(.036)	(3.827)	(7.586)		
All rural food products	1.4798	−.1423	−8.5550	55.7135	.899	.93
	(.275)	(.048)	(5.086)	(10.081)		
Rural nonfarm goods	.0225	−.0020	−.1660	−.8581	.199	.92
	(.030)	(.005)	(.548)	(1.087)		
Rural services and ceremonial	−.5781	.1198	8.4604	−14.7721	.490	2.00
	(.153)	(.027)	(2.833)	(5.617)		
All rural nonfood products	−.5556	.1178	8.2944	−15.6302	.528	1.40
	(.153)	(.027)	(2.832)	(5.613)		
All rural products	.9243	−.0245	.2607	40.0833	.944	1.00
	(.226)	(.039)	(4.189)	(8.303)		
Small-urban products	−.0147	.0168	.4216	−12.8134	.309	1.62
	(.100)	(.017)	(1.859)	(3.685)		
Large-urban products	.0142	.0010	−.3960	−5.4285	.260	.39
	(.043)	(.007)	(.793)	(1.571)		
Imported products	.1040	.0065	.2180	−21.7191	.518	1.07
	(.162)	(.028)	(2.995)	(5.937)		

[a] Figures in parentheses are standard errors. The probability level at which parameters are significantly different from 0 can be determined using a one-tailed t-test.
[b] Computed at the mean expenditure level.

from both small and large urban centers are quite low. To some extent this reflects the small industrial base in Sierra Leone which provides only a limited range of consumer goods. However, it is significant that the share of expenditures allocated to small urban areas almost doubles from the lowest to the highest income group, reflecting increasing demands for transportation services and small-scale industry goods produced in market towns serving the nearby rural areas. Although the percentage of increased rural incomes allocated to small-urban goods and services is not high, the rural population, because of its large share of the total, constitutes an important source of demand for the growth of small urban centers.

Finally, as indicated in the discussion of factor intensities, there is a tendency for higher income households to allocate an increasing proportion of incremental incomes to

Table 4. Marginal Propensities to Consume by Income Class for Commodities Grouped by Origin

	Marginal Propensity to Consume						
		Income Class					
Origin Classification	Mean Expenditure Level	Lowest Decile	Second and Third Deciles	Fourth and Fifth Deciles	Sixth and Seventh Deciles	Eighth and Ninth Deciles	Highest Decile
Rural subsistence food products	.445	.684	.588	.497	.436	.370	.286
Rural purchased food products	.216	.153	.178	.201	.218	.235	.257
All rural food products	.661	.837	.765	.698	.654	.605	.543
Rural nonfarm goods	.011	.013	.012	.011	.011	.010	.009
Rural services and ceremonial	.112	−.036	.023	.080	.117	.158	.211
All rural nonfood products	.123	−.023	.035	.091	.128	.168	.220
All rural products	.784	.814	.801	.789	.782	.773	.763
Small-urban products	.055	.034	.043	.051	.056	.062	.069
Large-urban products	.020	.019	.019	.020	.020	.021	.021
Imported products	.141	.133	.137	.140	.142	.144	.147
Total	1.000	1.000	1.000	1.000	1.000	1.000	1.000

imported goods, but the effect is not large. Significantly, in Sierra Leone at the present time, a larger share of incremental rural incomes is being allocated to imported commodities than to urban produced commodities.

Conclusions

In this study, data from a specially designed survey have been used to analyze empirically economic linkages based on rural consumption patterns and their variation with income level in rural Sierra Leone. Our results show that the labor, capital, and foreign exchange requirements of an additional unit of expenditure do not vary greatly by income level, particularly when compared to other studies in developing countries. There is, however, a definite tendency for the labor requirements to decrease and foreign exchange requirements to increase as incomes rise. Capital requirements fall with increasing incomes, reflecting a substitution of imported goods for capital-intensive domestic goods—that is a substitution of one scarce factor for another, rather than the substitution of scarce capital for relatively abundant labor. These results indicate that there need be no inherent conflicts between the objectives of output, employment, and income distribution. More equitable distributions of income should lead to little change in combined marginal requirements for the scarce factors, capital, and foreign exchange, and a clear increase in employment, which should reinforce improvements in the income distribution. It is also significant that increases of rural incomes are largely spent on labor-intensive commodities. Eighty-four percent of all marginal expenditures are for goods produced in small-scale, labor-intensive sectors—agriculture, fishing, small industries, and small-scale services. It is likely that the real difference in factor intensities of consumption patterns in Sierra Leone occurs between rural and urban consumers.

A major proportion of increased rural incomes is spent on commodities produced in rural areas. The next most important source of goods for rural consumers is imports. This implies that the multiplier effects of rural consumption patterns will largely be felt in rural areas. Rural consumption linkages with urban sectors are relatively minor, with the most important potential demand linkages being for goods and services from small urban areas that act as market towns for rural areas. Goods and services produced by large-scale firms located in Freetown, the largest urban area, are scarcely being consumed in rural areas. The products of large-scale industrial firms, consisting of items such as beer, soft drinks, biscuits, suitcases, and ready-made cigarettes, are largely oriented toward the higher income urban consumer. At the same time, rural demands for such items as cloth, shoes, and cooking ware are largely being met by imports. Clearly, however, the rural population is an essential source of demand for rapid industrialization, and efforts should be made to promote industries, both small and large scale and in both rural and urban areas, which produce goods for rural consumers.

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Water Utilization and Reallocation in Chile: A Study of the Pirque Valley

Loren L. Parks and David E. Hansen

The 1967 Water Code requires equalization of water rights per hectare in each "homogeneous farming area." Analysis of a typical area using linear programming models of representative farms indicates that equalization of water allocations per unit of land would result in regressive income redistribution, whereas the optimum economic reallocation would result in progressive income redistribution. Aggregate income gains in either case would not exceed 5%. Given the extreme inflexibility of the existing water distribution system, the transactions costs of changing water allocations would probably exceed benefits.

Key words: Chile, income distribution, water allocation.

With few exceptions, the responsibility of irrigation water management throughout Latin America lies ultimately with national governments (Crosson, Cummings, Frederick). The principal legal vehicle used to allocate water is the concept of "beneficial use," which generally limits each farm's water allocation to the quantity required for one hectare of a specified combination of crops (Daines and Falconi). Although interpretation and application of the concept differ by country, all allocation schemes are characterized by the pervasive role of government and the absence of economic efficiency criteria. In part, this paper examines efficiency problems associated with a particular irrigation system common to Chile.

Complicating any water management program is the issue of income distribution, which is increasingly taking precedence over efficiency issues in Latin America. In the case of Chile, considerable pressure has been exerted on decision makers to assure that water allocations are distributed "equally" within agriculture. This paper also examines institutional and economic problems associated with water reallocation schemes, and estimates changes in total farm income and income distribution among farms which would result from various water reallocation alternatives in a selected region.

Interpretation of the Chilean Water Code

The Agrarian Reform Law of 1967 included a new Water Code which nationalized water and changed the position of water rights holders to recipients of water concessions (Jensen). A government agency—the Dirección General de Aguas (DGA)—was created simultaneously to enforce the Code, i.e., to reallocate irrigation water according to a "standard of rational and beneficial use."[1] This irrigation standard is defined in Article 27 of the Code (República de Chile) as follows:

> The standard of rational and beneficial use of irrigation water shall be understood to be the annual volume of water, with its monthly distribution, necessary to cul-

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[1] According to Jensen the term "rational" reflected a desire to replace the traditional allocation with one determined by ostensibly objective technocrats. "Beneficial" justified limited indemnity for expropriated water rights. If a landowner held water rights in excess of the standard determined by the DGA, the excess would automatically be "unbeneficial" and subject to expropriation without compensation.

tivate one hectare of land considering the predominant or preferred crops of the region, the ecological conditions of the region, and the use of efficient irrigation technology. The maximum annual volume of water, with its monthly distribution, shall be determined for a farm on the basis of the standard of rational and beneficial use per hectare multiplied by the number of hectares to be irrigated.

The stated objective of Article 27 is to allocate an equal quantity of water per hectare to all farmers in a homogeneous region, thereby replacing "unfair" allocations previously secured by wealth or privilege. Interpretation of Article 27 was left to DGA technicians, who traditionally have been composed of engineers and agronomists. All interpretations have therefore employed purely physical criteria to define the critical terms and phrases such as "region," "ecological conditions," "efficient irrigation technology," and the "necessary quantity of water." The general approach has been to synthesize an average crop mix for one hectare of land, estimate potential evapotranspiration for that hectare using the Blaney-Criddle formula, and adjust final water requirements to reflect some level of irrigation efficiency.[2] The principal problems with this approach are that definition of a homogeneous region is arbitrary, no farm is likely to conform to the average hectare with respect to crop mix or physical resources, and irrigation efficiency is usually unknown. As a consequence, determination of irrigation standards has become a complex but arbitrary procedure which eludes the idealistic goals of objectivity and equity intended by the authors of the law. In all fairness, however, the DGA is confronted with an intractable water distribution system.

The Typical Chilean Irrigation Distribution System

Even if the irrigation standard were determinable, the nature of the existing water distribution system places severe limitations on the ability to allocate water with the precision implied in Article 27. A typical distribution system routes river water through a canal matrix using gravity flow. The canal matrix can be visualized as the branches of a tree where a Y-shaped structure called a *marco partidor* (dividing frame) is located at each fork, and where each branch terminates at a farm. The *marco partidor* divides the water in the trunk canal into predetermined proportions for the smaller canals (e.g., 70% to one canal and 30% to the other). Each farm receives a continuous flow of water which varies in quantity according to the number of water rights the farm controls and the stochastic rate of river flow. A water right is defined as a fixed percentage of the water in the river. Each farmer is assessed a small annual fee per water right controlled; there is no charge for quantity received.

Once water enters the farm it may be used immediately, stored for subsequent use, or allowed to flow through and become lost to that farm. Neither bypassed water nor field runoff enters that particular canal matrix again, but rather flows through small ditches that drain back toward the river. Part of this water is recaptured before reaching the river and part is lost to weeds, deep percolation, and evaporation. Water that drains back into the Maipo River can be diverted into other canal matrices downriver.

Since the *marco partidores* follow in series, a change in the dividing proportions of one *marco partidor* necessarily changes the quantity of water that flows through every canal downstream. A change in one farm's water rights (i.e., percentage of total water) would therefore change the number of rights available to all downstream farms. Not only are water allocations interdependent, but they are physically difficult to change because the steel blade which divides water in the *marco partidor* is set in concrete. This extreme inflexibility virtually precludes the fine-tuning required to reallocate irrigation water by any criteria. Reconstruction would be very expensive and would require substantial gains in efficiency to be economically justifiable.

Study Area and Methodology

Setting aside the problems of legal interpretation and physical intractability, the Pirque Valley—an irrigated area typical of central Chile—was selected for estimating farm incomes under alternative water allocation patterns. Pirque lies adjacent to the Maipo River, approximately 50 miles south of Santiago. In

[2] The Blaney-Criddle formula is used to determine the quantity of water evaporated from the soil and transpirated by the crop (evapotranspiration) in a specific area during a specific time. "Irrigation efficiency" is used in the agronomic sense of water quantity applied, although definitions and measurement techniques vary widely.

the 1974–75 crop year, 23% of approximately 6,000 cultivated hectares (all irrigated) were devoted to tree crops and grapes, 19% to grains, 25% to corn and vegetables, and 32% to forage—principally alfalfa.

The Pirque Canal Users' Association allocates 8.35% of Maipo River water among Pirque farms with a nominal precision of thousandths of a water right (one right equals 0.013% of total river water). The current allocation of water rights among farms ranges from 0.020 to 0.140 per hectare, with the distribution clustered around the mean of 0.098 rights per hectare (weighted by farm size). The variation in rights is due to legal and engineering factors concomitant with piecemeal extension of the canal matrix over time. The driest area tends to be the last irrigated.

The Maipo River flow rate—and hence the quantity of water associated with a water right—is highly variable because only one small reservoir on a Maipo tributary lies between Pirque and the Andean snow fields. Historical flow data are used to specify monthly water supply per water right corresponding to 80% certainty of supply. In the month of October, for example, the quantity of water per right was at least 21.79 thousand cubic meters in 80% of the Octobers from 1912 through 1971. Selection of 80% certainty of supply is subjective; it merely represents the best guess of the level that farmers implicitly use in planning their crop mix. A lower level of certainty would be associated with greater water quantity.

The Representative Farm Models

All 118 farms of 5 hectares and larger were surveyed, and three farm-type categories were determined based on (*a*) farm size, (*b*) type of ownership, (*c*) types of crop and noncrop activities, and (*d*) degree of specialization in those activities. Characteristics of the farms in each category are shown in table 1. One typical farm was selected in each category to serve as the basis for construction of a static linear programming (LP) model representing one year of operation. The farm types modeled are a cooperative (430 hectares), a medium-sized private farm (80 hectares), and a small private farm (10 hectares).

The three farm models share certain characteristics. First, the only binding restraints are land and water. Once a farm's labor and machinery resources are exhausted, for example, additional resources can be hired at the market price without limit. Second, the models include only field crops—wheat, alfalfa, clover, corn, and silage—because inclusion of vegetable and tree crops adds considerable complexity to the analysis with negligible difference in results. Third, the production activities for each crop represent discrete points along a continuous production function where all physical inputs except water and irrigation labor are held constant. Functions relating crop yield response to water were estimated using data from evapotranspiration experiments and adjusted to reflect the lower yields and input quantities observed on these farms. Fourth, the models employ identical input-output coefficients for crop production because only minor differences could be discerned in this small valley characterized by homogeneous technology and physical environment. Fifth, the objective function assumed in all three models is maximization of gross revenue less variable expenses (gross

Table 1. Characteristics of Farm Type Categories for Farms Surveyed in Pirque, Chile, 1974

	Farm Type Category		
Characteristics	Small Private	Medium Private	Cooperative
Farm size (hectares)	5–30	31–150	>150
Number of farms	84	23	11
Percent of total land	18	28	54
Water rights per hectare			
Mean	0.105	0.098	0.094
Standard deviation	0.032	0.026	0.026
Type of crop-noncrop mix	subsistence dairy, field crops	no dairy, field crops	commercial dairy, field crops with limited alfalfa
Degree of specialization	high	intermediate	low
Farms with reservoirs (%)	27	46	73

margin). Finally, it is assumed that half the water captured for irrigation is ultimately evapotranspirated (Tosso and Heilbraum).

The cooperative farm is jointly owned and managed by sixty-seven workers and the government land reform agency, the Corporación de Reforma Agraria.[3] A dairy and calving enterprise composed of 325 milk cows and nearly 600 other head of various ages dominates crop mix with alfalfa, clover, and corn silage being the principal feeds grown. Purchasing and selling activities for alfalfa are included in the LP model since there is an active market for that crop, but clover and silage are limited to farm production and consumption. Various other feed ingredients can be purchased. The LP solution generates the least-cost combination of feed production and purchases to meet the nutritional requirements of a fixed number and composition (by age, sex, and size) of livestock for one year. In addition to milk, calves, and alfalfa, corn and wheat can be produced for sale.

Production alternatives for the private farms include wheat, alfalfa, and corn. The small farm is assumed to maintain three cows for family milk and cheese consumption, hence clover for feed is also a production alternative. The medium farm does not maintain livestock.

Aside from the cooperative farm's dairy and calving enterprise, the principal differences among the farms are labor and machinery resources. The land/labor ratio for the three farms is approximately 12 hectares per man on the cooperative farm (after deducting dairy workers), 8 on the medium farm and 5 on the small farm. Since the regular farm labor force is a fixed cost in each case, variable labor costs are only incurred when temporary extra labor is hired.[4] The cooperative farm owns relatively more machinery than the other farms—particularly a grain harvester. The smaller farms have greater need for rented machinery, the daily cost of which is nearly double that of ownership. Finally, the cooperative farm is restricted to 60% of its land in alfalfa—the most profitable crop alternative—whereas the others are unrestricted.[5]

Particular mention must be made of the difficulty of obtaining believable factor and product prices in 1974. Inflation varied between 15% and 30% per month; there were periodic absences of some factors and products from the market; and some seasonal product prices fluctuated enormously. Product prices set by the government (wheat and milk in this study) were adjusted intermittently, often doubling or tripling in one fell swoop. Prices were therefore gathered at a "slice in time" (August 1974) and adjusted, if necessary, to reflect the relative prices that prevailed during the years immediately prior to the Allende regime. All monetary values reported herein are converted to U.S. dollars at the rate of 1,000 Escudos to $1. Product and input prices, as well as further details about the farm models, are reported in the study by Parks.

Income-Water Supply Curves

The quantities of water associated with different numbers of water rights per hectare at 80% flow probability are substituted into the resource vector of each LP model to generate the relationship between farm gross margin and water supply when the variable cost of water is zero (figure 1). Gross margin is expressed on a per-hectare basis to remove the influence of farm size. The principal characteristics of figure 1 are (*a*) all farms demonstrate diminishing economic returns to water; (*b*) the cooperative farm reaches maximum gross margin with fewer water rights per hectare than the other farms; (*c*) gross margin per hectare is greater the larger the farm, given relatively few rights per hectare, but the pattern is reversed when the farms have a relatively large number of rights per hectare; and (*d*) marginal returns to additional water decrease more rapidly with larger farm units. Diminishing gross margins per hectare occur as irrigations and crop yields increase because

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[3] The military government has declared that cooperative farms will eventually be divided into small private farms with producers' cooperatives formed to share indivisible assets. Nevertheless, some large private farms will remain, and producers' cooperatives will retain much of the identity of the original large farms.

[4] Labor is a fixed cost on the cooperative farm because workers are also owners and cannot be dismissed. Similarly, the 80-hectare farm owner cannot arbitrarily dismiss workers under the traditional employment system. The small farm is operated almost exclusively by family labor.

[5] Analysis of crop specialization by Parks revealed four principal reasons why this alfalfa restraint should be imposed: (*a*) crop rotation, (*b*) diversification, (*c*) labor limitations, and (*d*) desire to use the grain harvester which has a high fixed cost. Although temporary labor is assumed hirable in the LP models to isolate and compare the income differences due to water, some cooperative farms will not hire outsiders (*afuerinos*) for fear that they will try to establish claim to permanent partnership. Medium and small farms often rotate crops on a whole-farm basis, and some specialize completely in a single crop.

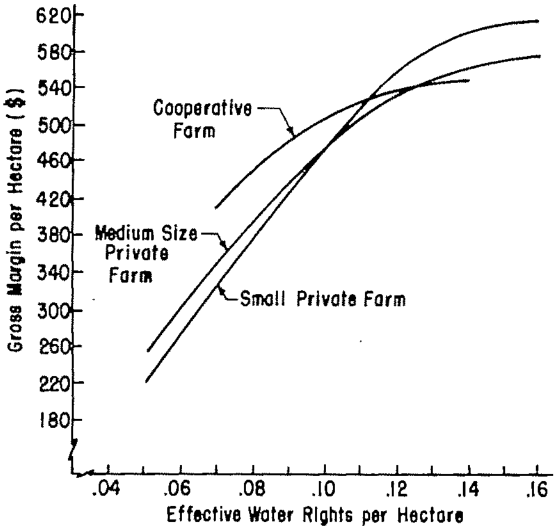

Figure 1. Farm gross margin for different levels of effective water rights at 80% flow probability

extra labor and tractors must be hired at a cost higher than using the farm's own supply. In addition, the cooperative farm reaches maximum gross margin with fewer water rights per hectare because the proportion of land planted in alfalfa is restricted. This helps explain why the cooperative farm has the lowest gross margin per hectare above 0.13 rights per hectare. Another reason is that the private farms have relatively more labor than the cooperative farm, and hence are not obliged to hire proportionally as much. Below 0.01 rights per hectare the pattern is reversed; the cooperative farm has the cost advantage of harvester ownership (the others rent) as wheat is substituted for alfalfa, and a dairy that is relatively profitable compared to the water-restricted crop alternatives.

The 10-hectare farm's income-water supply curve lies below that of the 80-hectare farm for less than 0.10 water rights per hectare principally because of the relative unprofitability of the poor quality animals maintained by peasant families. The 80-hectare farm's relative disadvantage in labor and tractor supply forces more hiring of extra supplies as water supply increases, hence gross margin per hectare falls below that of the 10-hectare farm above 0.10 rights per hectare.

The Results of Alternative Water Allocation Programs

Since water delivery is continuous, on-farm water storage reservoirs are frequently used to capture night flow that would otherwise be lost. Approximately one-third of the 118 farms in Pirque use reservoirs, but the incidence of use increases with farm size such that two-thirds of the total irrigated land area is affected (table 1). Use of a reservoir increases a farm's effective water supply, hence it is important in the analysis of water allocation which follows to distinguish between "nominal" and "effective" water rights. If a farm has 0.10 nominal rights per hectare but captures only half, it has 0.05 effective rights per hectare available for use. Farm reservoir construction and use are unregulated, hence government allocations of nominal rights are made in ignorance of effective rights. The following analysis examines the effects of three allocations of nominal rights—the current allocation, the equal water-rights per hectare allocation, and the optimum economic allocation. In all cases farm gross margins are determined for effective water rights, i.e., after allowance for the current pattern of reservoir use.

Gross margin for each farm in Pirque under the current water rights allocation is determined by locating the farm's effective number of water rights per hectare on the income-water supply curve for that farm type. Total gross margin for each farm type group is the simple summation of the gross margins of farms in that group (table 2).

Equalizing nominal water rights per hectare at 0.098 would result in a regressive income redistribution, but a slight increase of 3.3% in aggregate gross margin. The small farm group loses 3.1% of gross margin compared to the current allocation, whereas medium and large farms gain 7.2% and 3.2%, respectively. Among small farms there are thirty-two water losers and nineteen gainers with a heavy concentration of losers on farms of 12 hectares or less (twenty-three lose and five gain). Among medium farms, ten lose and nine gain; and among large farms, three lose and five gain. The medium farm group registers an income gain even though the average number of rights per hectare does not increase. This occurs due to diminishing economic returns to water; the marginal income loss from decreasing toward 0.098 rights per hectare is exceeded by the marginal income gain from increasing toward 0.098.

The optimum economic allocation of irrigation water among farms is determined by equalizing their value of marginal products (VMP's) of water at the level where the total

Table 2. Aggregate and Farm-Type Gross Margins for Current, Equal, and Optimum Allocations of Nominal Water Rights, Pirque Valley, Chile, 1974

Alternative Water Rights Allocations[a]	Farm-Type Category: Small Private	Medium Private	Cooperative	Farm Aggregate
Current average nominal rights/Ha.	0.105	0.098	0.094	0.098
Gross margin ($ thousand)	295	515	782	1,593
Equal nominal rights/Ha.	0.098	0.098	0.098	0.098
Gross margin ($ thousand)	286	552	808	1,646
Percentage of income change from current allocation	−3.1	+7.2	+3.2	+3.3
Optimum nominal rights/Ha.	0.112	0.098	0.085	0.098
Gross margin ($ thousand)	365	544	752	1,661
Percentage of income change from current allocation	+23.7	+5.3	−3.9	+4.3

[a] Allocations are made at the farm level, implying that within-category, as well as between category, reallocations occur.

quantity of water demanded equals total supply. A water VMP function for each farm type was obtained by generating an LP solution for each of a series of water prices with no restriction on water supply (Moore and Hedges). The equilibrium water price of $12.50 per thousand cubic meters allocates the small, medium, and cooperative farms 0.122, 0.098, and 0.085 nominal water rights per hectare, respectively. Under the optimum rights allocation, large farms lose 3.9% of gross margin compared to the current allocation, whereas medium and small farms gain 5.3% and 23.7%, respectively. A positive income redistribution would result, as well as a small increase in aggregate income of 4.3%.

Conclusion

If the results generated for Pirque are representative of other areas in Chile, they generally argue against comprehensive water reallocation programs. Equality, pursued through equal per-hectare water allocation, will result in economic inefficiency and a worsened income distribution. While the optimum economic water allocation would considerably improve income distribution, aggregate income gains would be quite small. It seems implausible, therefore, that benefits could exceed the expected high transactions costs associated with determination of the irrigation standard for each "homogeneous" area, reconstruction of the water delivery system, and administration and enforcement of the reallocation.

Some alternatives exist for mitigating current inefficient or inequitable water allocations while maintaining the existing delivery system. A scheme of *turnos* ("taking turns") is used in some areas to divert abundant quantities of water through one canal branch in lieu of a small quantity through all branches simultaneously. With this method less water is bypassed, farmers can irrigate better because of increased water velocity, and delivery time can be adjusted to compensate for differences in water rights. The principal difficulties with this method are a dearth of water control gates and the danger of overflowing and damaging the unlined canals.

A second alternative for modifying water allocation is increased use of farm reservoirs to capture night flow. This alternative cannot be recommended a priori, however, because six other canal associations downriver from Pirque depend on return flows to the Maipo for part of their water supplies. Increased water consumption in Pirque would certainly inflict negative economic externalities on farms downriver, but without measurements of return flows or the value of water downriver, the net impact on economic efficiency and income distribution in the river basin cannot be estimated.[6]

A third alternative that economists might suggest for modifying water allocation is water pricing—particularly marginal-cost pricing. This is currently impractical because there are no water measuring devices in use, because farmers use only a portion of the water they

[6] Although night irrigation would appear to be an alternative to farm reservoirs, the existing irrigation technology precludes it. The field flooding method requires the irrigator to walk among the plants directing water to dry spots by making small channels and barriers with a spade—a task he could not accomplish without light.

receive, and because the transactions costs of changing the water delivery system would probably exceed benefits.

The existing water delivery system has some advantages which should not be overlooked. Inflexibility is accompanied by some level of certainty, in the sense that it would be very difficult for administrators to exercise capriciousness or favoritism to perpetrate greater injustices and inefficiencies in water allocation. Furthermore, it is impossible for farmers to acquire concentrations of water rights except through land concentration, but reversal of the land reform already completed is highly unlikely. Finally, conflict among farmers is minimized with the existing arrangement. In the long run, altered technology could cause the inefficiencies of the current system to increase, but at present the system appears to have considerable appeal both in terms of efficiency and equity.

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Rural Banks and Farm Loan Participation

Peter J. Barry

Banking theory is used to develop a static, certainty model for evaluating profitability of farm loan participations for rural banks. Techniques are developed and applied to measure empirically the effects of participations on rural bank earnings attributed to farmer customer relationships and costs associated with demand balances required by correspondent banks. Model results show a decline in optimal levels and profits of loan participations for rural banks as correspondent balance requirements increase and as other parameters adjust to levels reflecting tighter monetary conditions. Participation strategies that may enhance the flow of funds into rural areas are also considered.

Key words: agricultural finance, correspondent banking, loan participations, rural banking.

Rural banks have long relied on loan participations with correspondent banks to meet farm loan requests that exceed their legal lending limits and to meet total loan demands that are high relative to available loan funds (Swackhamer and Doll; Hopkin and Frey; Federal Reserve Board of Governors 1975).[1] Generally, the participating banks both carry portions of the loan, each receiving interest and security on their respective shares. In addition, the correspondent bank is also compensated by demand balances held on deposit by the rural bank (Meinster and Mohindru, Knight 1970a).

These loan participations tend to work well when monetary conditions are relatively stable. However, problems in the pricing mechanism for participations appear to increase significantly a rural bank's participation costs during periods of rapidly rising interest rates, as occurred in 1969 and 1974, and, in turn, seriously impair the bank's ability to meet fully the financing needs of larger farm units. The pricing problem is attributed to the use of balances to pay for correspondent services, a practice which has been criticized for its tendency to overcompensate for the services and cause a net outflow of funds from rural areas (American Bankers' Association; Benjamin; Federal Reserve Board of Governors 1975).

This paper's purpose is to provide empirical evidence on the responses of correspondent balance requirements in loan participations to changing monetary conditions and to evaluate their effects on participation profitability for rural banks. Banking theory is used to develop a static, certainty model of participation profitability for a rural bank and to develop techniques for empirically measuring some of the variables affecting earnings and costs. Participation costs are evaluated with data obtained from a simulated loan participation designed to measure the balance and other credit requirements of a sample of correspondent banks. Emphasis is also given to measuring the influence on rural bank earnings of deposit growth arising from the loan participation. The profitability model is then used to evaluate participations under two monetary conditions and to identify participation strategies that may enhance the flow of funds to rural areas.

The Profitability Model

The profitability model measures only the rural bank's earnings and costs that are attrib-

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[1] For nationally chartered banks, loans to an individual borrower cannot legally exceed 10% of the bank's paid-in capital and unimpaired surplus fund, although the limit increases to 25% for loans to purchase livestock. Loan limits for state chartered banks vary among the respective states although generally appearing somewhat larger than limits for national banks (Swackhamer and Doll). In Texas, for example, analysis of bank balance sheets indicated that about half of the Texas banks at year-end 1972 had legal lending limits of less than $200,000 (Paulson).

uted to the correspondent's level of participation in farm loans. Neither the rural bank's portion of the participation, its use of other correspondent services, nor its risk of loss of the farmer's deposits are considered. Participation costs for the rural bank are clearly identified as the opportunity cost of added balances required by the correspondent to compensate for the participation.

The rural bank's earnings from the participation are less apparent, but nonetheless significant. Rural banks receive no interest on the correspondent's share of the participation and seldom pass the compensating balance requirements along to farm borrowers (Barry, Greathouse, Boondiskulchok). However, the correspondent's participation does enable the rural bank to retain the farmer's deposits and earn greater income in the future by investing any deposits fed back to the rural bank as a result of the loan funds provided by the correspondent.

This temporal linkage between lending and deposits is a unique, significant feature of banking that has several facets. Hodgman identified the customer-deposit relationship by showing the importance of demand deposits as a primary source of a bank's capacity to lend and invest, and the resulting importance of the bank's relationship to loan customers who hold demand deposits. Hodgman further showed how bank competition for deposits is expressed through interest rate policies, compensating balances, and other customer services. Wood extended Hodgman's customer-deposit relationship to multi-periods by showing how a liberal lending policy may induce increases in future deposits that can, in turn, be loaned or invested, and added the customer-loan relationship which suggests that a bank's current lending policy also influences its future loan demands. Wood's theoretical results show that a bank's profit-maximizing allocation of deposits between loans and securities exhibits marginal returns on lending that include the interest return on current loans plus the present value of earnings attributed to future loans and deposits arising from the customer relationships. In contrast, the marginal returns on securities having no customer relationships include only interest.

The feedback between lending and deposits for an individual bank is essentially a micro application of the deposit-creating phenomenon that characterizes an entire banking system (Samuelson, chap. 16). Lending to bank customers is assumed to cause part of the loan proceeds to return to the bank as deposits, while no such feedback occurs from investment in securities that involve an outflow of funds from the bank's market area. The fedback deposits occur from the combined effects of (*a*) the borrower's increased business growth arising from the financing, (*b*) the borrower's increased level of deposits prior to spending the loan proceeds or repaying the loan, and (*c*) the increased level of business activity in the community. The fedback deposits provide the basis for additional loans whose demand may be strengthened by the current loans. These additional loans generate fedback deposits, which provide for additional loans, and so on. Less than complete feedback to the individual bank and reserve requirements on deposits are the main constraints on deposit expansion (Pesak and Saving, chap. 11).

The temporal linkage between loans and deposits is modified in several ways in the case of loan participations. First, the rural bank's new loanable funds arising from loan participations occur from the initial feedback of deposits on loans provided to farmers by correspondent banks. Second, any increased loan demand that utilizes fedback deposits must generally come from other borrowers rather than from participating farmers. The farmers' loans from the rural bank are constrained by its legal lending limit, which is determined by the level of bank capital. Although changes in bank capital do occur, these changes are generally attributed to risk bearing and growth rather than to a need for new legal lending limits (Paulson, Orgler and Wolkowitz). Finally, the loan participation helps to reduce the risk of loss of the farmers' deposits and loans.

The model of participation profitability is developed under conditions of static certainty, with assumptions that the rural bank is a price taker in purchasing securities and an imperfect competitor in loans. Let z be the rural bank's rate of deposit response, defined as the increase in loanable funds resulting from the correspondent's loan participation L. Let i_e be the returns on loans that are made from fedback deposits with loan demand function $i_e = \alpha - \beta L$. If the rural bank's costs of participation are represented by a rate of compensating balance requirement k on participation L with opportunity costs i_f, then the rural bank's

profits π from participations are

$$(1)\qquad \pi = zLi_e - kLi_f.$$

Substituting for i_e and expanding terms gives

$$(2)\qquad \pi = \alpha zL - \beta zL^2 - kLi_f.$$

Considering the level of loan participations as the decision variable, the first order condition for a profit-maximizing level L^* is

$$(3)\qquad d\pi/dL = \alpha z - 2\beta zL - ki_f = 0,$$

which gives optimal participation

$$(4)\qquad L^* = \frac{\alpha z - ki_f}{2\beta z}.$$

Suppose, for example, that $z = .3$, $k = .2$, $i_f = .05$, $\alpha = .10$ and $\beta = .0000001$. Optimal loan participations L^* are then \$333,333.

Totally differentiating (4) with respect to parameters i_f, k, z, α, and β indicates their respective influences on L^*. Results are

$$(5)\qquad dL^*/di_f = -k/2\beta z < 0,$$

$$(6)\qquad dL^*/dk = -i_f/2\beta z < 0,$$

$$(7)\qquad dL^*/dz = 2\beta ki_f/(2\beta z)^2 > 0,$$

$$(8)\qquad dL^*/d\alpha = 1/2\beta > 0,$$

and

$$(9)\qquad dL^*/d\beta = \frac{2z(ki_f - \alpha z)}{(2\beta z)^2}$$
$$< 0 \text{ if } ki_f < \alpha z$$
$$< 0 \text{ if } ki_f < \alpha z.$$

Increases in opportunity costs (i_f) or in balance requirements (k) result in lower levels of loan participation. Opportunity costs are strongly influenced by effects of financial market conditions on yields of financial assets, while balance requirements are determined by correspondent banks. Increases in deposit response (z) and in the intercept (α) of the loan demand function increase optimal loan participations. Changes in deposit response are generally attributed to changes in bank loan policy and to factors in the rural bank's market area. Shifts in the loan demand function are generally caused by changes in the borrower's income, past loans, and other farm-related factors. Participation responses to changes in the slope (β) of the loan demand function cannot be evaluated without knowing the parameter values. In reality, all these parameters usually change simultaneously and it is difficult to identify their individual effects on the optimal level of loan participations.

Data Needs

The empirical analysis uses equation (4) to evaluate how changes in monetary conditions, as reflected by new parameter values, influence the profit-maximizing level of loan participation for a model rural bank. Two monetary periods are used—"1975 Conditions" is a lower interest rate period and "1974 Conditions" is a higher interest rate period.

Empirical estimates of each parameter in equation (4) are needed to evaluate participation profitability. Estimates of correspondent balance requirements (k) and rates of deposit response (z) are not readily available and require appropriate measurement techniques. The loan demand function and opportunity costs of balance requirements are estimated from secondary sources.

Correspondent Balances

Balance requirements on loan participations are determined from the procedures for Customer Profitability Analysis (CPA). CPA is a relatively new tool used by many large, urban banks to evaluate the profitability of any customer relationship. For loan participations, CPA combines analysis of the profitability of providing nonparticipation services, such as check clearing, currency exchange, computer and broker services, and safekeeping with analysis of the profitability of providing loan participations. Knight's (1975a,b) review of the approaches to CPA indicates much variation in its use; however, basic CPA concepts are similar in all these approaches.

This analysis expresses the CPA model as the correspondent's net rate of return (R) on equity capital that it commits to support the loan participation.

$$(10)\qquad R = \frac{[(kL)(1 - h_c)(i_o) + i_pL - L(1 - c)(i_f)](1 - t)}{cL}$$

Three items comprise the net returns of the participation as expressed by the bracketed terms in equation (10). First is the rate of earnings i_o on the rural bank's collected balances (kL) held at the correspondent in compensation for the loan participation, reduced by the correspondent's rate of reserve requirement (h_c). Collected balances are total balances less uncollected funds or float that may result when rural banks clear cash items

through correspondents, but which are not immediately available for use. The second item is the interest rate i_p on the loan participation (L). The third item reduces returns by the cost (i_f) of nonequity capital committed to the participation. Banks generally consider that part (c) of the loan participation is financed by their equity capital, with the rest financed by debt capital. As is customary in CPA analysis, the rate of return R is expressed after taxes by multiplying the numerator by $1 - t$, where t is the corporate tax rate.

To measure balance requirements empirically, nine major correspondent banks in Texas were asked to evaluate a case loan request from the model rural bank, with the interviewer serving as the rural bank's manager (Boondiskulchok). The model bank was described in terms of its size, legal lending limit, loan-to-deposit ratio, use of correspondent services, and other measures of performance. In addition the model rural bank was assumed to need participation on fifteen of its loans ranging over a variety of purposes and totalling \$4.06 million. The number of participation requests was set high enough to anticipate the correspondent's rejection and designed for deletion of individual requests until approval was obtained.

Each correspondent was asked to indicate their preferred level of participation and their requirements on rates of return, compensating balances, or both, for the two monetary periods. Two kinds of responses occurred (table 1). Correspondents 1, 5, 7, and 9 used CPA and responded in terms of the net returns on capital required for participation. These rates of return are reported in lines 3 and 5 of table 1 for both periods. Those correspondents not using CPA responded in terms of the compensating balances required for participation. The use of CPA appears directly related to a correspondent's level of participation. If credit quality and net returns on capital are acceptable, correspondents using CPA were all willing to participate up to \$4.06 million. Others would participate only in lower amounts (line 1).

Further data are needed to use the CPA model in equation (10). Interest rates on loan participations (i_p) are designated as 10% for 1974 conditions and 8.5% in 1975. Both rates were verified by correspondents as representative for the respective years (Boondiskulchok). Average annual federal funds rates of 10.51% in 1974 and 5.96% in 1975 serve as the correspondent's costs of funds (i_f) (Federal Reserve Board of Governors 1974–75).[2] Interviewed correspondents indicated that the earnings rate (i_a) is generally about .25 percentage points below the cost of funds. Hence the earnings rate is designated as 10.26% in 1974 and 5.71% in 1975. A reserve requirement (h_c) of 17.5% and a capital requirement (c) of 10% are each judged appropriate from information provided by the correspondents. The corporate tax rate (t) is 48%.

The measures in parentheses in lines 2 and 4 of table 1 are the rates of compensating balance k that are needed to yield the designated required rates of return on capital for the two

[2] Federal funds refer to immediately available funds that are exchanged, through lending and borrowing arrangements, between banks and other financial institutions. The exchange is typically for one night and is facilitated through a member bank's reserve account at a Federal Reserve Bank.

Table 1. Summary of Correspondent Responses to Simulated Overline Loan Requests

	Correspondent Bank 1	2	3	4	5	6	7	8	9
1. Overline participation (\$1,000)	4,060	1,575	2,505	2,505	4,060	2,155	4,060	2,155	4,060
1975 Conditions									
2. Compensating balance, k (%)	(15.1)	10	20	20	(15.1)	15	(15.1)	10	(15.1)
3. Net return on capital, R (%)	20	(18.8)	(21.2)	(21.2)	20	(19.9)	20	(18.8)	20
1974 Conditions									
4. Compensating balance, k (%)	(45.9)	30	35	35	(39)	30	(39)	30	(39)
5. Net return on capital, R (%)	23	(16.0)	(18.2)	(18.2)	20	(16.0)	20	(16.0)	20

Note: Numbers in parentheses are derived from other data with procedures described in the text.

periods, given the measures on other variables in equation (10). As an example, under 1975 conditions, correspondent 1 requires a 15.1% compensating balance in order to achieve a 20% net rate of return on capital. Under 1974 conditions, the compensating balance requirement rises to 45.9% to meet a 23% rate of return on capital for the same level of participation. Similarly, the measures in parentheses in lines 3 and 5 are the rates of return on capital in each period that result from the designated compensating balances, given the other variables in equation (10). In the following profitability analysis, these rates of balance requirements are assumed to hold for all levels of participation.

While farm loans requiring participation are generally "prime" to the rural banker, they are generally not "prime" to the correspondent. Many correspondents assign their loans to different risk classes, each requiring different rates of return on capital. As an example, one correspondent required a 16% return on class 1 loans (prime), a 20% return on class 2 loans, and a 24% return on class 3 loans. The required rates varied with changing monetary conditions. Most farm loan participations fell in classes 2 and 3.

Deposit Response

The rate of deposit response z for a rural bank is defined as

$$(11) \qquad z = D(1 - h_r)/L,$$

where D is the level of deposit response, h_r is the rural bank's legal reserve requirement on deposits, and L is the amount of loan participation. The level of deposit response depends upon the availability of new loanable funds, the reserve requirement, and the rate of loan-deposit feedback. In loan participations, the rural bank's new dollar of loanable funds arises from the initial deposit feedback on the correspondents' loan to the farmer. To illustrate: let f be the feedback rate defined as the percentage of loans that return to the bank as deposits with $0 \leq f \leq 1$, h_r be the reserve requirement with $0 \leq h_r \leq 1$, and n be the number of deposits. The total deposit response (D) on loans from the fedback deposits resulting from the loan participation is modeled by the following geometric progression:

$$(12) \quad D = fL + (f)(1 - h_r)(fL) + [(f)(1 - h_r)]^2(fL) + , \dots , + [(f)(1 - h_r)]^{n-1}(fL).$$

The first term to the right of the equality reflects the new dollar of loanable funds arising from the initial feedback on the loan participation. The following terms then reflect the series of fedback deposits on loans generated by the feedback, net of the reserve requirement.

Taking the geometric sum of (12), as n grows infinitely large, yields equation (13) for estimating the deposit response:

$$(13) \qquad D = \frac{fL}{1 - f(1 - h_r)}.$$

Equation (13) is abstract of time and implies that the deposit response from the entire feedback series occurs instantaneously. Suppose, for example, that $f = .5$, $h_r = .13$, and $L =$ \$1.00. The deposit response is then \$.88. Moreover, calculations with equation (12) indicate that much of the deposit response occurs in the early phases of the series. In the example, \$.81 of the total response is recovered in three iterations. Results also show that fedback deposits increase as f increases and as h_r decreases. If $f = 1$, the deposit response is \$7.69, and if $f = 0$, the deposit response is zero.

The magnitude and timing of f are strongly influenced by bank size, bank competition, loan characteristics, and the borrower's liquidity management. Changes in monetary policy and legal constraints also influence deposit growth apart from a bank's lending activities, as do changes in population, employment, disposable income, and nonbank sources of funds in the bank's market area. This complex of influences makes it difficult to use historic bank data to isolate the loan-deposit feedback. Hence, an alternative measurement approach is developed to estimate a banker's perceived rate of feedback.

This approach assumes that a banker can choose between investments in loans and securities that have comparable risk and liquidity solely on the basis of their yields. Net yields on securities with no customer relationship are determined by interest rates less servicing costs. Returns on lending consist of loan interest less service costs plus the earnings on additional lending supported by the fedback deposits. Under these conditions, one can expect a differential in the banker's designation of indifference or break-even yields on securities and loans that solely reflects the banker's perception of the additional earnings generated by the fedback deposits. As an example, the banker might indicate that

a net yield of 8% on securities provides total returns equivalent to a net yield on lending of 6%, leaving him indifferent between the two investments. The 2% differential reflects his estimate of the earnings attributed to the feedback.

The perceived rate of feedback is estimated by combining the indifference yield differential with the feedback model of equation (13). To illustrate, let the following variables be the indifference yields: i_e is the net yield on loans and i_s is the net yield on securities. Total earnings (E_s) of investing the initial feedback (fL) from the loan participation, net of reserve requirements, in securities are

$$(14) \qquad E_s = (i_s)\,(fL)\,(1 - h_r).$$

Alternatively, total earnings (E_L) of investing the initial feedback of deposits in loans with further feedback are

$$(15) \quad E_L = (i_e)\left[\frac{fL}{1 - f(1 - h_r)}\right](1 - h_r).$$

To find the rate of feedback that yields equality between total earnings on securities and loans, set (14) equal to (15), cancel terms and solve for f. Further modification gives

$$(16) \qquad f = \left(\frac{1}{1 - h_r}\right)\left(1 - \frac{i_e}{i_s}\right).$$

Thus, for indifference yields of 6% on lending and 8% on securities and a reserve requirement of .13, the estimate of feedback is

$$f = \left(\frac{1}{1 - .13}\right)\left(1 - \frac{.06}{.08}\right) = .2874.$$

The differential yield method for loans and securities was used to estimate the rate of deposit feedback as perceived by a small sample of rural bankers in south central Texas (Podolecki). Eleven banks in five small, rural towns chosen on the basis of similar size, location, and other community characteristics were asked to participate in a simulated investment situation. These similarities helped to standardize the setting for the bankers' responses. While the interview approach limited the sample, it provided a realistic setting and allowed the interviewer to more readily gain meaningful banker responses.

The bankers were asked to abstract from the complexities of day-to-day banking in order to consider investments in either a \$100,000 prime loan to an agricultural borrower or a \$100,000 purchase of U.S. treasury bills. Each investment had a nine-month maturity. The net loan yield reflected prevailing interest rates less costs of servicing and administering the loan (Functional Cost Analysis). Each banker was then asked to estimate the yield on treasury bills net of servicing costs that would provide equivalent profitability to the specified loan yield.

The \$100,000 figure was judged large enough to elicit meaningful responses from the bankers, but not so large as to require reconsideration of overall lending policy. Hence, both choices were assumed to meet the bank's legal and policy constraints. Designating a prime loan customer served to reduce loan risks as far as possible, although government securities are generally considered less risky than loans. Bankers were also assured that any risk of deposit loss from failure to make the loan was quite low. While the maturities on the two investments were equal, the availability of secondary markets likely favors the treasury bill's liquidity. Nonetheless, differences in risk and liquidity between the two investments were assumed to be minimal, thereby implying that any differences in yields designated for the two investments were attributed to the feedback.

Only one banker declined to respond, citing the absence of any tangible information for response. The other ten responses are summarized in table 2. Columns 2–4 identify each bank's Federal Reserve System membership, net demand deposits, and reserve requirement, respectively. Column 5 indicates the net yield specified for the agricultural loan. Two loan yields were used because several bankers felt a lower yield was more realistic. The difference in loan yields has no effect on calculating the feedback rate, nor did it appear to influence the relative yield differentials. Column 6 indicates the bankers' designation of security yields that provide the same profitability as the specified loan yields. Column 7 indicates the feedback rates calculated with equation (16).

One banker indicated an infinite indifference yield on treasury bills implying, in effect, an infinitely high rate of feedback and a very strong customer relationship. Feedback rates for the other nine bankers ranged from .1008 to .4371, and averaged .2884. The standard deviation was .1217, indicating relatively high variability among the responses.

The mean feedback rate f = .2884 is used to determine the rate of deposit response z by solving equation (11):

Table 2. Loan-Deposit Feedback Rates Derived from the Lender Survey

Bank	Membership Status[a]	Net Demand Deposits, $ million[b]	Reserve Requirement, Demand Deposits	Loan Yield	Securities Yield	Loan-Deposit Feedback Rate
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	N	15.027	.150	.08	.11	.3208
2	N	16.674	.150	.06	.075	.2353
3	N	10.940	.150	.06	.0672	.1253
4	N	9.401	.150	.06	.09	.3922
5	M	9.987	.095	.06	.09	.3683
6	M	34.371	.113	.08	.12	.3760
7	M	35.352	.113	.08	.13	.4336
8	N	25.196	.150	.08	.0875	.1008
9	M	18.733	.107	.08	.10	.2240
10	M	9.152	.094	.08	∞	∞
Average (banks 1–9)						.2884
Standard deviation (banks 1–9)						.1217

[a] Symbols M and N refer to membership and nonmembership in the Federal Reserve System, respectively.
[b] Net demand deposits are gross demand deposits minus cash items in the process of collection and demand balances due from domestic banks.

$$z = \frac{D(1-h_r)}{L} = \frac{\left[\dfrac{fL}{1-f(1-h_r)}\right](1-h_r)}{L}. \tag{17}$$

Letting $h_r = .13$ and canceling L yields $z = .335$. The rate of deposit response, $z = .335$, will be used in the profitability analysis. However, several features of the feedback concept and its method of estimation warrant further discussion.

Each banker agreed that lending and deposit activities are closely linked. They also observed that any quantitative estimate of the linkage is quite speculative. Indeed, their processes for reaching indifference yields appeared to be based primarily on intuition and expectations about future customer relationships and financial conditions. In addition, the bankers were assumed to regard prime agricultural loans and U.S. treasury bills as comparable in risk and liquidity, to choose on the basis of net yields rather than gross yields, and largely to disregard the risk of deposit loss.

Variations in the bankers' acceptance of these assumptions may significantly influence their responses. If, for example, bankers attributed part of their yield differential between loans and securities to risk of the farmer's deposit loss, then the derived rate of feedback is biased upwards. Similarly, if bankers attributed part of their yield differential to costs of loan risk and loan servicing that are higher than the simulated costs, then again the derived rate of feedback is biased upwards. While the simulated investments were designed to minimize occurrence of these responses, the derived feedback rates may best be considered as estimates of upper bounds on the actual rates.

More general concerns are how the feedback rate differs among loans, among borrowers, and with differences in bank structure and competition. Some observers (e.g., Woodworth, Samuelson) feel that feedback for individual banks in a competitive banking system is quite small and that only very large banks, often organized in a branching system with considerable market power, realize much feedback. This conclusion is based on the premise that for smaller banks in highly competitive markets, the likelihood is simply too low that borrowers leave their loan proceeds unspent or that they are redeposited in the same bank or trade area.

However, recent research (e.g., Heggestad and Mingo) and empirical observation suggest that rural banks generally operate in less than perfectly competitive markets. Rural communities are generally isolated from metropolitan areas with relatively few institutions competing for deposits (Jessup and Stolz). Entry of new banks is highly regulated, although new entry tends to promote greater competition (Fraser and Rose). Existing banks tend to be small and often have limited managerial capacity. Objectives other than profit maximization are often prominent. While difficult to document, access to high

quality investment information appears more limited in rural areas, resulting in little movement of savings from the area.

Agricultural loans also differ considerably in their risk and liquidity. Repayment risks from variability in commodity prices, production, and managerial quality are often large. Loan liquidity is low due to the relatively fixed nature of business assets pledged as loan security and the absence of well organized secondary markets for selling the notes. Finally, the proceeds of many farm operating loans are used to purchase inputs from local suppliers, thereby adding to business activity in rural banking markets.

All these factors combine to strengthen the importance of the loan-deposit feedback in rural banking. Moreover, the general awareness of the feedback exhibited by the interviewed bankers together with the realism of the simulated investment help give confidence in the reliability of their responses. Hence the rate of deposit response $z = .335$ is used in evaluating the rural bank's profit maximizing level of loan participations.

Loan Demand and Opportunity Cost

Parameters (α, β) of loan demand are derived from a loan demand function estimated by Boehlje and Fisher with data from a sample of rural banks and banking markets in Oklahoma. They obtained the following demand function for agricultural production loans:

$$(17)\quad AGPROD = -372{,}823.0 - 99{,}106.4T - 2.18CPI + 1{,}572.44IFP + 1.097\,(AGPROD - 2) - 93{,}929.7\,(r_p) + 8{,}381.6RI,$$

where $AGPROD$ is the six-month stock of agricultural production loans; T is a seasonal dummy that equals 1 for June 30 and 0 for December 31; CPI is annual county personal income ($1,000's); IFP is an index of farm prices; RI is a weather index; r_p is the annual interest rate on agricultural production loans; and $AGPROD - 2$ is the stock of loans ($100's) lagged two six-month periods.

This loan demand function is reduced to a price-quantity relationship by specifying appropriate values for all variables other than the interest rate. For 1975 conditions, these variables are CPI = $32,496,000, IFP = 480, $AGPROD - 2$ = $3,850,000, T = 0, and RI = 79.[3]

[3] Values of exogenous variables for 1974 and 1975 were provided by Clint Roush, Oklahoma State University.

Table 3. Parameter Values for Loan Participation Model

Parameter	1975 Conditions	1974 Conditions
α	.1072	.1435
β	.0000001066	.0000001066
z	.3350	.3350
i_f	.0596	.1051
h	.1300	.1300
k		
Bank 1	.1510	.4590
2	.1000	.3000
3	.2000	.3500
4	.2000	.3500
5	.1510	.3900
6	.1500	.3000
7	.1510	.3900
8	.1000	.3000
9	.1510	.3900

Carrying out the calculations and transposing terms to match the loan demand function for i_e in equation (2) yields $i_e = .1072 - .0000001066L$. For 1974 conditions, values of these variables are specified as CPI = $29,450,000, IFP = 640, $AGPROD - 2$ = $3,600,000, T = 0, and RI = 88. The resulting loan demand function is $i_e = .1435 - .0000001066L$.

The opportunity cost of correspondent balances is assumed to be the same as the correspondent bank's cost of nonequity funds, as described earlier. Hence, average federal funds rates of 5.96% in 1975, and 10.51% in 1974 serve as the rural bank's cost of holding correspondent balances.

Results

Table 3 summarizes the data used in the profitability analysis and table 4 indicates the rural bank's profit-maximizing levels of loan participation L^* and net profits π^* with each of the nine correspondent banks for the two monetary periods. Profit-maximizing levels of participation are derived with equation (4), while net profits are measured with equation (2). Results for 1975 conditions are considered as a norm for comparing the results for 1974 conditions with tighter credit and higher inter-

Table 4. Profitability of Loan Participations

	Correspondent Bank								
	1	2	3	4	5	6	7	8	9
1975 Conditions	$								
1. Optimal loan participation L^*	376,774	494,385	335,891	335,891	376,774	377,614	376,774	494,385	376,774
2. Profits π^*	5,070	6,080	4,029	4,029	5,070	5,093	5,070	6,080	5,070
Change in balance requirement									
3. Optimal loan participation L^*	119,711	252,443	210,719	210,719	177,396	252,443	177,396	252,443	177,396
4. Profits π^*	511	2,276	1,586	1,586	1,123	2,276	1,123	2,276	1,123
1974 Conditions									
5. Optimal loan participation L^*	−1,960	232,001	158,494	158,494	99,549	232,001	99,459	232,001	99,549
6. Profits π^*	negative	1,915	892	892	352	1,915	352	1,915	352

est rates. Lines 1 and 2 of table 4 indicate values of L^* and π^* for 1975 conditions. Lines 3 and 4 indicate values of L^* and π^* when the rates of compensating balance (k) increase to levels given for 1974 conditions, while values of other parameters remain at levels for 1975 conditions. Lines 5 and 6 indicate levels of L^* and π^* when values of all parameters adjust to levels for 1974 conditions.

Under 1975 conditions, optimal loan participations range from $335,891 with net profits of $4,029 at correspondents 3 and 4 to $494,385 with profits of $6,080 at correspondents 2 and 8. As expected, the highest levels of participation occur with correspondents having the lowest balance requirements. In addition, as indicated by the comparative static analysis in equation (6), increases in compensating balances to 1974 levels decrease the optimal level and profitability of participations with each correspondent. For example, the rural bank's profit-maximizing level of loan participations with correspondent 1 is $376,774 for 1975 conditions, with net profits of $5,070. As balance requirements from correspondent 1 increase from 15.1% to 45.9% for 1974 conditions, optimal loan participations decline to $119,711, with net profits of $511.

Comparative static analyses also indicated that optimal levels of participation respond positively to increases in α and negatively to increases in i_f and k, with the net effect determined by the relative magnitudes of changes in these parameters. When parameters α and i_f are also adjusted to 1974 levels, levels of participation and profitability decline further because the relative increase in opportunity costs (i_f) of correspondent balances exceeds the rate of increase in the intercept term of the loan demand function. For correspondent 1, optimal loan participations become negative as parameters are adjusted to 1974 levels.

A similar pattern of declining levels and profits of participations for 1974 conditions is exhibited by correspondents 2 through 9, although the responses are less pronounced because these correspondents have lower balance requirements than does correspondent 1. For example, optimal participations from correspondent 2 decline from $494,385 for 1975 conditions to $252,443 as the balance requirement increases from $k = .10$ to .30, and further decline to $232,001 as other parameters adjust to 1974 levels. As expected, levels of participation are lower and less profitable from correspondents requiring relatively larger increases in balances, although positive levels of participation still occur under 1974 conditions from all but correspondent 1.

Implications

Results of the profitability analysis clearly show the decline in the rural banks' optimal levels and profits of loan participations as correspondent balance requirements increase and as other parameters adjust to values reflecting tighter monetary conditions. Hence, the availability of participation loans to farmers will likely decline in tighter monetary periods because of the rural banks' profitability response.[4] These results also indicate that

[4] Further study is likely needed to determine how rural banks have responded to these participation problems. For example, Benjamin found that rural banks in Illinois obtained a lower volume of credit services from Chicago correspondents in 1969—a tight monetary period—than in the relatively easier conditions of 1968. However, this decline in loan participations and other credit

monetary policies designed to raise interest rates and tighten credit may severely restrict the availability of bank loans to those farmers and nonfarm borrowers whose credit needs are great enough to require loan participations. Under these conditions, monetary policies may have a more significant impact on the structure of agriculture than is generally believed.

The availability and costs of participations are primarily influenced by the correspondents' customer profitability analysis (*CPA*), with their willingness to participate determined by the ability of the participation to meet the profit standards. These standards appear to fluctuate with changing monetary conditions but generally remain high enough to reflect the correspondents' risk of participating. In addition, the use of demand balances as a method of profit adjustment on loan participations makes it difficult for rural banks to meet precisely the correspondents' profit requirements. As table 1 indicates, relatively wide changes in interest rates in financial markets together with rather limited adjustments in rates on farm loans cause large fluctuations in balances required by correspondents to meet their profit standards.

Several responses to the cost and pricing problems associated with loan participation can be identified. One is direct referral of farm customers by the rural banker to the correspondent for loan servicing, risking loss of their deposits and other banking business. Another possibility is to let the correspondent originate the loan and sell a portion back to the rural bank, leaving the deposit and loan servicing functions with the rural bank. Still another possibility is for the rural bank to retain the farmer's deposits but arrange financing with other local lenders.

Several strategies can also be identified to help enhance the rural banks' current use of loan participations and thereby improve farmer access to nonlocal sources of funds. One strategy involves the use of fee payments instead of balances to compensate for individual correspondent services; however, fee payments appear to have little use (Benjamin). Another strategy is for rural bankers simply to learn more about their correspondent's methods of evaluating participations in order to identify lower cost sources of participation and reduce holdings of excess balances. A third strategy is to continue holding excess balances at one or more correspondents so as to use more easily participations when needed. A fourth strategy is to provide additional balances only when needed to compensate for loan participations. Finally, a few rural bankers (e.g., Walton) have experimented with selling general participation shares in loan pools to correspondents as a source of liquidity when loan demands are high.

Another set of strategies reflects methods of passing the full costs of funds along to the farm borrowers. Passing along compensating balance requirements has received relatively little use on farm loans. Letting interest rates play a more dominant and responsive role in loan participations may be promising. Using variable interest rates on the correspondent's portion of the loan could eliminate the need for variation in balance requirements. Moreover, it might encourage correspondents to lengthen the maturities on their loan participations. The interest rate could be set at the correspondent's prime loan rate plus a fixed premium (e.g., 2%) plus a fixed compensating balance (e.g., 20%). The interest rate then would fluctuate with changes in the prime rate, which in turn are induced by changes in other market interest rates. The rural bank clearly would know the balance requirement, while the correspondent still would meet its profit requirement. Moreover, the borrower would pay the changes in the costs of funds. Several of the interviewed correspondents indicated that they have encouraged rural banks to use variable interest rates on loan participations.

Finally, various features of the customer relationship need further study for their effects on loan participations as well as on other areas of rural banking. This study largely disregarded risks of the farmers' deposit loss and loan default associated with loan participations, although these factors may strongly influence bank behavior. Further study of methods for measuring the feedback rate is also warranted. Other simulated investment situations could evaluate variations in feedback among loans differing in maturity and purpose, among borrowers who are depositors versus nondepositors, and among loans to depositors who reside in different locations. Also, study of historic bank data reflecting actual deposit growth, market shares, lending, purchases of securities, and other factors af-

services appeared to be offset by increased services from correspondents in other areas.

fecting bank performance merits consideration in measuring feedback rates.

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The Food and Agriculture Act of 1977: Issues and Decisions

R. G. F. Spitze

While the Food and Agriculture Act of 1977 has much in common with previous legislation and continues the evolution of agricultural and food policy, important changes are made in grain reserves, food stamps, procedures for setting target levels, support prices, acreage bases on individual farms, as well as administration and funding of research and education. Some consequences are evident, but much will depend upon unpredictable events of weather and foreign markets. The results of the Act, as compared to no policy, are traced for consumers, producers, foreign trade, and U.S. Treasury payments, under alternative scenarios. If shortages return, much of the law becomes irrelevant.

Key words: agricultural and food policy, 1977 Act, price and income policy.

The Food and Agriculture Act of 1977 is not a new, imaginative policy, nor is it an old rerun. Rather, the Act signals a continued evolution of public price and income policy within the United States. It will have significant effects on U.S. farmers, consumers of food and fiber, traders, taxpayers, and the people of other nations. Yet, the future of the agricultural and food sector is likely to be shaped as much by unpredictable events in the national and world economies as by the contents of the Act. If the world's food production per capita actually declines similar to 1972 and 1974, this new Act could be as irrelevant as the past one. This article analyzes the background, development, provisions, consequences, and research implications of the policy embodied in the Food and Agriculture Act of 1977.

Conceptual and Problem Framework for the Act

The 1977 Act, as a piece of public policy, was directly shaped by the private policy of innumerable citizens, both on and off the farm, and by diverse interest groups concerned with the many issues surrounding the food system. It follows that a major responsibility of public institutions responsible for agricultural research and education is the creation and dissemination of dependable information intended for use by citizens in fashioning their own policy.[1]

Evolution of Agricultural and Food Policy

The 1977 Act has been heralded as a new policy direction and put down as a resiphoning of old vintage. However, it can best be described as a stage in the evolution of policy. Public agricultural and food policy is evolving as a merger of early farm policy, then agricultural policy, and recently food policy. The concerns for developing a productive agriculture during our nation's first century and a half have expanded over the past twenty-five years to include food—consumer concerns about quality, availability, and cost (Bonnen, Farrell). Instead of a "new policy agenda," the better characterization would be as a continually evolving policy agenda. The 1977 Act vividly portrays this evolution. A cynic might observe that conflicting goals were forged together for political expediency, while the student of public policy would see the compromise as symbolic of the policy process.[2] The

Note: This article was invited by the editor.

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[1] A substantial, but admittedly incomplete, sample of this flow of professionally written input during the development of the Act appeared in four issues of the newsletter *Policy Research Notes*, which listed 152 separate items released during 1976–77, related to the analysis of price and income policy.

[2] Representative F. Richmond, an urban New York member of

1977 Act joins the long succession of public price and income policies inaugurated by the Agricultural Marketing Act of 1929, which established the Federal Farm Board. This heritage includes the Agricultural Adjustment Act (AAA) of 1933, Soil Conservation and Domestic Allotment Act of 1936, AAA of 1938, Steagall Amendment of 1942, Agricultural Acts of 1948, 1949, 1954, 1958, Agricultural Trade Development and Assistance Act of 1954, Soil Bank of 1956, Emergency Feed Grain and Agricultural Acts of 1961, Food and Agricultural Acts of 1962 and 1975, Food Stamp Act of 1964, Agricultural Act of 1970, and Agriculture and Consumer Protection Act of 1973 (Rasmussen and Baker). Each, in turn, set a different policy course. During the early 1960s, high price supports tied to parity and compulsory acreage allotments evolved into the recent policy package featuring price support levels near "world market levels," voluntary land retirement, target prices tied to cost-of-production escalators, and compensatory payments (Spitze 1968, 1972).

Price and Income Problems Persist

Unfortunately, the age-old scourge of farm price and income instability and of periodically lagging income levels that have been so scholarly documented do not fade away (Cochrane, Wilcox, Houck, Robinson, Brandow). All too vivid for policy watchers of the 1977 legislative season were the gyrations of the past fifteen years: farm product prices that were more variable than wholesale prices; consumer food prices slightly more unstable than those of other final goods; farm product prices receding relative to prices paid by farmers, except for two years; and total farm income figures per capita oscillating from 58% to 109% of those for nonfarm income.

Policymakers were faced with the question: Are the recent lush years the vanguard of the future or only a lull before the price and income plague returns with a vengeance? The key is the balance between the supply and the demand for U.S. agricultural products. For 1976, the increase in aggregate agricultural output was 2.6%. Balanced against this on the demand side were population, which increased 0.7%, and increased income with an estimated total demand effect of 0.4%. This left 1.5% of the additional supply to be met by new net exports and government acquisitions. Yet, net exports showed no real increase and acquisitions were small. Price elasticity concepts suggest that such a margin likely would result in a price erosion of more than 5%. By the fourth quarter, in fact, farm product prices had declined 6% from the previous year and total net income was dropping. Of course, with a jump in net exports, the opposite could have been the scenario, with rapidly rising farm product prices.

Favorable Farm Productivity Record

A helping hand is reluctantly extended by the public to an ailing sector whose economic performance lags, but the choice is easier when the productivity record is strong. So it was with the 1977 Act. The agricultural and food sector remains an economic asset and an interest that must be reckoned with politically, even in the presence of our increasingly urbanized, industrialized economy. While the nonagricultural trade deficit deepened in 1976, an agricultural trade surplus counterbalanced it and also yielded a net merchandise trade surplus of $3.5 billion for the economy. Strong growth in aggregate farm output and farm productivity have been recorded since 1950, with the exception of the 1960s (table 1). Then, a public policy of production control "diverted" 55 to 65 million acres of crop land annually from a total of approximately 350 million acres. Farm worker productivity compared to nonfarm is also impressive. These data and other analyses of agricultural trends do not suggest much deviation from the past (Yeh, Tweeten, Quance).

Impetus of Terminating Legislation

Since most price and income policy specifies a duration, the timing of the public's choice about such policy is usually fortuitous. Many decisionmakers, particularly in the executive branch, would have preferred a delay last year to assess the rapidly shifting events; but the expiration of the 1973 Act on 31 December 1977 signaled termination or reversion to earlier and already discredited approaches for most programs.[3] Little disposition prevailed to

the House Agriculture Committee and one of the leaders in achieving adoption of the Act, stated: "If food stamps were not in the farm bill you wouldn't have a farm bill. And if the farm bill were not with food stamps you wouldn't have food stamps." (Christensen)

[3] The content and status of existing legislation, which would set

Table 1. Changes in U.S. Farm Output and Productivity with Comparisons

Periods	Changes in Output: Farm Output[a]	Changes in Output: Private Nonfarm Business	Changes in Output per Worker Hour: Farm	Changes in Output per Worker Hour: Private Nonfarm Business	Changes in Farm Productivity (Output per Unit of Input)
			%		
1950–55	12.2	21.2	32.4	11.8	9.6
1955–60	9.6	11.9	44.4	9.7	15.0
1960–65	7.7	28.2	36.9	19.2	10.9
1965–70	3.1	16.0	25.8	7.8	−1.0
1970–75	12.9	9.9	25.9	6.0	11.9

Sources: U.S. Department of Agriculture. *Changes in Farm Production and Efficiency*. ERS Statistical Bulletin no. 561, Sep. 1976; Office of the President. *Economic Report of the President*. Jan. 1977.
Note: Total changes occurred during the five-year interval indicated from previous year.
[a] This procedure has the implicit possible problem created by a unique year; however, another computation using cumulative change on a five-year moving output index base revealed a very similar trend, although a smoother one.

permit either, so the search for a policy posture for 1977 and beyond proceeded.

Policy Alternatives and Decisions

The abortive attempt by the Congress to raise the farm commodity target and loan rates with H.R. 4296 in 1975 set the stage for the 1977 Act. Special attention given to food programs by the House and Senate in 1976 added to the theme. Momentum picked up with the return of a familiar Congress in the national election in November 1976; and studies and proposals flowed from every imaginable private and public group. The alternate policy packages generally considered were: (*a*) a simple extension of the minimal-impact, 1973 Act; (*b*) a moderate alteration and updating of the existing policy; (*c*) a major revision; (*d*) the dismantling of all public price and income policy; and (*e*) the initiation of substantial public control over the U.S. agriculture and food system.

Professionals in economic policy played an unusually active role through analysis and education.[4] These capabilities in the legislature had been significantly augmented with the expansion of congressional staff groups, such as those associated with the Congressional Budget and Impoundment Control Act of 1974, the new budget committees, and the Senate Select Committee on Nutrition.[5]

By the time the new 95th Congress was organized in early 1977, at least thirty-seven relevant bills had been introduced, including a pivotal bipartisan proposal by Senators Herman Talmadge and Robert Dole. This established a lead role throughout the drama for Senator Talmadge, chairman of the Senate Committee on Agriculture, Nutrition, and Forestry. That committee made the initial moves by generating widely circulated background publications and by launching lengthy public hearings in February. Secretary Bob Bergland had presented the administration's views in March, but the script prompting was clearly in congressional hands. The full Senate adopted its version of the new policy, S. 275, on 24 May 1977 (U.S. Congress. Senate Report 95–180). The House Committee on Agriculture, in extensive deliberation, spent a total of seventy-two days on its bill, H.R. 7171. That measure was adopted by the House on 28 July 1977, following an unusually lengthy seven days of floor debate (U.S. Congress. House Report 95–348). Food stamp reform, dealt with

the future policy course if either the 1973 Act were extended or left to expire without alternative action, is an important variable in the development of the 1977 Act. This knowledge is amply documented in the literature (USDA *Agricultural-Food Policy Review* and *Farm and Food Policy 1977*).

[4] Symbolic of many such efforts, in addition to analyses appearing in the professional journals, are ten products representing the work of Congressional and USDA staffs as well as national and regional professional workshop and publication efforts (ARPAC; Cornell University; Great Plains Agricultural Council; National Public Policy Education Committee; University of Illinois; USDA 1974, 1976, 1977; U.S. Congress, Budget Office; U.S. Congress, Senate, 1976, Farm and Food Policy 1977). They were developed specifically to present existing knowledge in the discipline objectively, with five relating to discrete alternate policy directions.

[5] Commencing in 1975, agricultural economists and economists as publicly employed analysts in the agricultural and food policy area in Washington, D.C., have been meeting to strengthen professional communications. They represented seventeen major services and agencies, several of which employed more than one such specialist. Numerous reports were issued by the budget committees, the food staff of the General Accounting Office, and the Select Committee which, in one release, called for a national nutrition policy (*Towards a National Nutrition Policy*).

by the House committee separately through H.R. 7940, was subsequently folded into the integrated food and agricultural policy finally adopted (U.S. Congress. House Report 95–464). Although economic analysis played an important part, the drama was clearly a political one, as is so characteristic of public policy development (Youngberg).

Alternate Policy Versions and the Choice

The final plot began to emerge around the House, Senate, and administration versions of an integrated 1977 agricultural and food policy. The similarities overshadowed the differences. Even so, the differences were not insignificant.[6]

Days of negotiation among the House and Senate conferees occurred in late July. The Senate strove for the higher public protection for commodities. The president threatened a veto. Urban spokesmen wanted a reformed food program for the poor and some labor and welfare trades. Consumer and charitable groups cried out for some signal of a commitment toward public grain reserves. Farm producers demanded that their costs be locked in and that embargoes be locked out. The House wanted a signed bill. Agreement was finally achieved 5 August on a conference version which the Senate approved on 9 September 1977, by a vote of 63 to 8. This was followed by a favorable House vote of 283 to 107 on 16 September. The curtain call had brought forth moderate alteration and updating, truly a compromise cast on middle ground, well within the conceptual framework of public policy. President Carter signed the Food and Agriculture Act of 1977 on 29 September, thus setting the course of public price and income policy in the agricultural and food sector for the next four years.

Policy Provisions

As the most comprehensive one in the succession of price and income policies, the 1977 Act encompasses a great many provisions. These can only be summarized. The Act amends most of the legislation going back through the still-existing AAA of 1938. The text extends through 150 pages of the Conference Committee Report (U.S. Congress. House Report 95–599). Substantial administrative discretion is left to the secretary of agriculture. The Act supplies a direction and boundaries, within which the executive branch must set and implement policy. In numerous areas, the scope of the options is considerable.

To some critics, the 1977 Act appears to be a jumble; but simplicity is challenged by any policy attempting to integrate agricultural and food issues. Furthermore, order can be found in this Act. Its provisions can be clustered around four primary problem areas.

Food Distribution

Both domestic and foreign food aid programs are encompassed. Food Stamps and Supplemental Food for Women, Infants and Children (WIC) are the domestic ones. The Food Stamp Program was first operated 1939–41, reinstated in 1961, and expanded rapidly commencing in the late 1960s to increase food purchases of low income people. That program now reaches about 8% of our population. WIC, initiated in 1974 and expanded rapidly, provides food aid to pregnant and nursing women and to young children whose need for an adequate diet is critical.

The P.L. 480 program, as foreign food aid, appeared in 1954, during the buildup period of public stocks. Agricultural products are now transferred in three ways under P.L. 480; namely, food donations to countries experiencing disaster, sales of products on easy credit terms, and the use of local currency sales for designated self-help efforts. This program has been operating primarily through concessional sales. Much less quantity is being distributed currently to the roughly eighty recipient countries than was distributed in earlier years.

Both the P.L. 480 and Food Stamp programs previously followed a policy path separate from that of the commodity programs. The 1977 Act identifies human nutrition as a basic responsibility of the U.S. Department of Agriculture and as a priority area for research and education.

Commodities

The 1977 Act covers price-support loans, target prices and deficiency payments, set-

[6] Provisions may be found in the alternate versions previously cited as S. 275, H.R. 7171, and the Food Stamp Act of 1977, and also from the administration proposal (Bergland). Treasury cost estimates were generated by the Congressional Budget Office (U.S. Congress. Budget Office. Staff Working Paper).

aside production control procedures, reserves, export embargo snap-back provisions, farm storage, grazing and hay permits, and disaster payments for wheat, corn, and other feed grains, soybeans, cotton, rice, peanuts, dairy products, and wool and mohair. Limitations were set on the deficiency payments related to wheat, feed grains, upland cotton, and rice. Some of these policy package features have been in operation since the 1930s to raise and stabilize farm product prices and incomes.

The price-support loan levels for applicable commodities are generally established as minimums, and are usually near the average domestic or world market prices. Discretion is provided to the secretary of agriculture to increase or moderately lower these levels. Target price levels for the first year are the result of a compromise decision related to all costs but responsive to some differences in assumptions about costs of production. However, the levels during subsequent years are mandated to escalate with the rise in average variable and overhead (not including land) costs of production, per unit and by commodity.

In the 1977 Act, uniformity on these and other important provisions, such as deficiency payments, set-aside procedures, export embargo provisions, and disaster payments, has been more nearly achieved than previously for the covered products. Furthermore, the 1977 Act is made more comprehensive by including most products with public price and income programs. Only tobacco remains outside.

Research and Extension

Major agricultural research, extension, and teaching programs previously treated in other legislation to support continued domestic agricultural development are now under the umbrella of the 1977 Act. Significantly higher funding ceilings are authorized, with considerable program and administrative control. Competitive grants for much of the additional support are mandated, and priority areas for both food and agriculture are identified. The USDA is established in more of a fundamental manner than before as the lead agency for channeling federal support to the food and agricultural sciences. A system of advisory groups with public and private members is created to assist the U.S. Department of Agriculture in this role.

Additional Items

Miscellaneous provisions for a variety of objectives, commodities, and programs have been placed in the 1977 Act, sometimes to insure the continuance of terminating legislation, at other times to address a new problem. A beekeeper indemnity program is continued. Filberts are included in the Marketing Agreement Act. Aquaculture is made a function of the USDA. An emergency feed program is set forth. Alterations are made to certain Farm Home Administration functions. The 1977 Act also covers phases of rural development, environmental enhancement, conservation, and funding for grain inspection.

A summary of selected major provisions and the primary implications is presented in table 2 U.S. Congress. House Report 95–599).

Primary Changes from the 1973 Act

An evolutionary path implies a combination of sameness and change. The 1977 Act offers both. Some changes parallel economic trends since 1973, such as raising the payment limitations. However, these substantially exceeded the rise in the index of farm prices. Some changes of economic significance will be highlighted.

Grain reserves. For the first time, public policy mandates a minimum level for a continuing national reserve of grain when supplies are abundant. During such times, the reserves must include 300–700 million bushels of wheat, adjusted by any commitment under an international agreement about reserves. This average of 13 million metric tons a year is little more than the minimal reserve usually called for in advocacy proposals (10–35 million metric tons). Yet, it stands as a departure from the past. Furthermore, discretion is provided to offer loans jointly held by the government and the farmer for three to five years. The extended loan period and the detailed specifications of the resale price band, 140% to 175% of the loan, signal policy changes from the low resale options exercised by administrations of all philosophies in the past. Whenever extended loans are in effect, the government may not sell grain stocks associated with its annual or resale price support programs for less than 150% of loan; otherwise the resale level is 115%. The only mandate is for a reserve of wheat. Of course, other grains, such

Table 2. Summary of Provisions of the Food and Agriculture Act of 1977

ITEM	PROVISIONS	IMPLICATIONS
DURATION	Four years, 1978-1981.	Issues settled for few years.
FOOD DISTRIBUTION Domestic	Food stamp program continued. Maximum $6.2 bil./yr. budgeted. Partial purchase requirement for stamps eliminated. Work requirement for able recipients to be eligible. Benefits reduced for high and raised for low income.	Slows cost escalation. Increases participation. Serves needy better. Simplifies administration. Attempts to reduce fraud.
	Women, infants, children (WIC) program continued.	Improves nutrition of pregnant women and infants.
Foreign	"Food for Peace," P.L. 480 continued. Requires more reporting of bids, payments, sales. Permits distribution of products not in "surplus."	Attempts to reduce fraud. Permits food aid in addition to just surplus disposal.
GRAIN RESERVES	Farmer-held reserve mandated with some discretion for Sec. 3-5 yr. extended loans available for grains. Wheat extended loan reserve must be 300-700 mil. bu. Reserve may be induced by free storage and interest. Farmer redemption of loans may be discouraged by penalty when prices below 140% loan, may be induced by fewer benefits when prices 140-160% loan, and forced when prices 175%. Govt. stocks resalable at 115% loan if no outstanding loans of that product; 150% otherwise.	Insures govt.-farmer controlled reserve for security of consumer, export market, and aid. Permits recall loans and resale govt. stocks during high prices and low reserves. Reduces high and low extremes of farm prices.
COMMODITIES Wheat	Price support (non-recourse loan), minimum: 1977 — $2.25/bu. 1978-81 — $2.35/bu. (may be lower by 10%/yr. to $2.00 if supplies heavy)	Increases stability of producer and consumer food prices. Results in stocks and possible reserves. Raises minimum export prices and provides stocks for possible exports.
	Target price assures national aver. return on planted acres within farm allotment to producers meeting any set-aside and other conditions: 1977 — $2.90/bu. 1978 — $3.05/bu. (1.8 bil. bu. harvest or less) — $3.00 (more than 1.8 bil. harvest) 1979-81 — escalates with rise in variable costs.	Maintains minimal producer incomes at levels somewhat related to rising costs of inputs. Results in variable govt. payments to producers.
	Set-aside out of current year's planted and normal crop acreage may be a condition for benefits: 1978 — 20% set aside (by Secretary of Agriculture)	Reduces large supplies relative to demand by voluntary action.
	Disaster payments available 1978-79 if plantings prevented and yields low due to natural occurrences.	Govt. payments reduce producer risk due to nature.
Corn (support on other feed grains proportional)	Price support (non-recourse loan), minimum: 1977 — $2.00/bu. 1978-81 — $2.00/bu. (as wheat, may be lowered to $1.75) Target price (same conditions as for wheat) 1977 — $2.00/bu. 1978 — $2.10/bu. 1978-81 — As wheat, will escalate with costs. Set aside out of current year's planted and normal crop acreage may be a condition for benefits. Approach to disaster payments same as for wheat.	Implications are same as for wheat, with price support also increasing stability of livestock prices.
Soybeans	Price support only, minimum: 1977 — $3.50/bu. (by Secretary of Agriculture) 1978-81 — Loan mandated but level at discretion of Sec.	Same as for corn, but no minimum mandated.
Cotton, rice, peanuts, sugar	Price support loans, target prices and/or set-aside established for each commodity	Effects similar to above but vary with combinations.
Payment limitations	Combined wheat, feed grain, cotton target payments limited (rice higher): 1978 — $40,000; 1979 — $45,000; 1980-81 — $50,000	Inducement for large producers to set aside is proportional to height of limit — and so are equity concerns.
Dairy	Price support dairy products continued, minimum: Until March 31, 1979 — 80% to 90% parity After March 31, 1979 — 75% to 90% parity Adjusted semiannually through March 31, 1981.	Same as for wheat, but effects are more direct to food consumers.
Wool and mohair	Price deficiency payments continued for all production at 85% of formula rate (figures at about 99¢/# for 1977).	Govt. payments to producers. Less dependence on imports.
RESEARCH AND EXTENSION	Funding ceiling increased for 5 years, emphasis on competitive grants, USDA lead role, human nutrition, veterinary schools, small farm help, 1890 colleges, solar energy, alcohol extraction, advisory groups roles.	Increases food and agriculture funds, relying more on grant approach and centralized administration.
ADDITIONAL ITEMS Export embargo	Secretary must raise price support to 90% parity upon suspension of normal exports of product with loan program.	Discourages public disruption of commercial exports.
Multi-year set-aside (if necessary)	Secretary may have multi-year set-aside contracts for feed grains, wheat, cotton.	Encourages permanency, conservation, sediment control.
Farm storage	Loans for farm product drying, storage, and handling.	Encourages loans and reserves.
Conservation	Funding eased for major soil conservation projects.	Encourages erosion control.
Grain inspection	Funding for grain inspection supervision.	Facilitates new program.

as feed grains and rice, can be added as discretionary reserves.

Publicly held stocks of commodities in evidence from the 1930s until the early 1970s should not be confused with reserves. Those stocks were an unwelcome fallout from an incongruence between the public's desire to raise support-price levels and to control production. A lack of commitment on the latter was revealed in the limitations imposed in the

control options and in their implementation. Those stocks were dispensed abroad and into the regular domestic market at permissible levels barely above loans, sometimes unexpectedly. Among the results were unstable markets and uncertain expectations. The same condition could result in a buildup now of large Commodity Credit Corporation stocks and substantial U.S. Treasury outlays if the provisions (of the new Act) to balance productivity and demand are not implemented properly. The grain reserve offers the possibility of increased food supply security, greater dependability as an exporter, more price stability, but also a diminution of the chances for windfall gains. The difficulties in the yet-untried management of such a program should not be minimized.

Food stamp program. for the first time, the cash purchase requirement for food stamps by eligible recipients has been eliminated. This can be expected to increase substantially participation from the lowest income group. This change is also likely to reduce the actual food purchases by those using food stamps, since the cash-purchase value previously used now can be partially or wholly diverted into nonfood consumption. In addition, changes in the Act relative to income eligibility standards, deduction procedures, and application processes will increase benefits to lower income recipients and decrease benefits to those with higher incomes. Finally, the work requirement was strengthened for appropriate recipients.

Target price escalations. Similar to the expiring policy, target prices for covered crops for the final three years of the Act will reflect cost changes. However, these will be per unit costs associated with variable inputs, machinery ownership, and general farm overhead operations on a product-by-product basis. Further, the cost changes will reflect a moving, two-year average instead of a one-year average; no adjustment will be necessary to reflect yield changes, as was previously the case. These changes remove the restraining effect of productivity, tend to smooth out volatile, cost-induced escalations, and add complication to the estimation of costs.

Cotton is treated similarly to the grains, with minimum target prices of 52¢ per pound in 1978 and 51¢ the following years. The loan levels will vary according to previous domestic and world market prices. The minimum price-support levels for the wool deficiency payment program determined by the formula rate are considerably higher than the fixed level of 72¢ a pound used in recent years, and also are likely to escalate.

The compromise target price levels are substantially higher in absolute terms than those of the previous act, as well as those of the abortive 1975 H.R. 4296. However, if all of the cost increases since 1972 were built into the then existing market prices with a procedure similar to that provided by the 1973 Act, they would present generally the same trajectory of price levels as the one built into the target prices of the 1977 Act. Yet, the new Act does appear to treat wheat and cotton more favorably than corn.

Soybean loan. A loan is mandated for soybeans for the first time; but the level is at the discretion of the secretary. In the past, that office held the authority about whether or not a loan was made and, if so, at what level. The 1977 Act now provides direct public sanction to use this policy instrument regularly for soybeans to achieve any desired objectives of production and pricing in the feed-livestock sector.

Set-aside and allotment base. For the first time, acreage bases on the farm, except for peanuts, to determine allotments, set-aside compliance, and target-price payments shift from the previously used historic period to the current or the preceding year's planted acreage. This permits greater flexibility by farmers, but the 1977 Act also complicates the discretionary decisions about the desired annual "package of policy instruments" and the prediction of results.

New sugar, rice, peanut programs. A departure in sugar policy is launched for 1977 and 1978 only. It involves loans and purchases to maintain a minimum price for raw sugar of 13.5¢ a pound, and may be suspended if a negotiated International Sugar Agreement insures the same price level. The secretary is also directed to set minimum wage rates for agricultural employees in this production area. Prior to 1974, when the old sugar acts expired as world prices skyrocketed, quotas were assigned to both domestic producers and to foreign producing areas in order to maintain price levels related to the cost of production and to profit.

The provisions of the 1975 Rice Production Act are continued under the 1977 Act, folding this crop into existing price-support, target-price, and set-aside policy covering the grains and cotton. That rice program shift had moved

rice from a high price-support and marketing-quota approach to the one embodied in the 1973 Act for grains. The new peanut program moves away from the existing price-support and mandatory-allotment approach to a two-price support system involving "quota" production and "additional" production. The quota production for peanuts now carries a minimum price support of $420 a ton.

Export embargo. Price supports must be raised to 90% of parity immediately for any normal export commodity for which a loan program exists and for which export suspension is instituted by the government. This should discourage the administrative use of this trade policy.

Agricultural research and education. Substantive changes are embodied in the 1977 Act for the funding, programming, and administration of federal and state programs in agricultural research, extension, and teaching. The true impact must await interpretative and implementing decisions. Considerably higher levels of federal funding are likely for the life of the Act, and the funds may largely flow through competitive grants. A greater centralization of administration via the USDA may occur. And more emphasis may be given to specified areas, such as human nutrition, the plight of small farmers, veterinary education, the programs of the 1890 Land Grant Colleges, solar energy, extracting alcohol from agricultural products, controlling animal diseases, and supporting promising efforts to make scientific breakthroughs.

Additional commitments. Among the various commitments of public purpose embodied in the 1977 Act, which in some cases may result in significant policy changes, are the following: the president is encouraged to enter into negotiations with other nations to develop an international emergency food reserve; the Congress reaffirms an historic policy to foster the family farm system of agriculture and directs the secretary to submit annually a report on current trends in family farms, nationally and by states, along with an assessment of the impact of existing public policy on the family farm.

Primary Consequences of the New Act

Detailed estimates of expected economic results for many of the alternate price and income policies being advanced were generated as the terminal date of the 1973 Act approached. As the specific House, Senate, and administration proposals took shape, even more careful projections were drawn by the USDA and by the congressional staff groups. These are a matter of record, many in professional literature previously cited. Yet, when the final compromise was struck, a unique "package of policy instruments" was created, for which careful analyses of consequences were not, and are not yet, available.

The consequences flowing from the new Act are dependent on the stated provisions as well as the interpretations and discretionary decisions to come. They are equally dependent upon the economic events yet to unfold surrounding the agricultural and food systems of our nation and the world. These range from the actions of the oil-producing nations through USSR purchases, and from General Agreement on Tariffs and Trade (GATT) negotiations to the weather in the North American plains.

To obtain some general insights, we will specify one broad set of assumptions about the next few years in the life of the Act.[7] We can then identify its related consequences for consumers, producers, traders, and the U.S. Treasury. Doing this will also permit us to track briefly two major alternatives from these assumptions. We assume (*a*) aggregate production of domestic agricultural products continuing at the average increase of about 1.8% per year, as in the past quarter century, during which some public production control prevailed for all years except the past three; (*b*) a domestic population increasing at the average rate of 0.8% per year; (*c*) a domestic income increasing an average real rate (per capita) of approximately 2% per year (or a real demand increase of approximately 3% per year); (*d*) real net exports increasing aggregate demand by approximately $550 million (1977 dollars) per year, or about 0.6% per year (approximately the average rate for the past decade and a half, excluding half of the unprecedented jump of net exports for 1972 and 1973 but including the other half); (*e*) variations in the world food and economic situation continuing, but without the unusual convergence of the unstabilizing events of the

[7] The recent historical trends of farm output, population, and trade, upon which these assumptions are largely based are derived from published data by USDA and the U.S. Department of Commerce, and the income elasticity of demand is assumed to be (+.1).

The Formulation of Price Expectations: An Empirical Test of Theoretical Models

B. S. Fisher and Carolyn Tanner

Price expectations are an important part of many models of economic behavior. In spite of this, little is known of the process by which decision makers formulate their expectations when making actual decisions (for two studies on the subject, see Turnovsky, and Heady and Kaldor). The aim of this study is to test various hypotheses about the formulation of price expectations, using data obtained from individual decision makers.

In the development of aggregate models of agricultural supply response, uncertainty about how individual farmers formulate price expectations has led, in many instances, to the uncritical use of a number of assumptions and hypotheses. The adaptive expectations hypothesis, originally applied to agricultural supply-response analysis by Nerlove, is one of the most commonly-used (Duloy and Watson, Anderson and Saylor). According to this hypothesis, expected price in the current period is a geometrically weighted average of past prices. However, recent supply-response studies undertaken by Meilke, Zwart, and Martin, and Fisher (1975), using polynomial distributed-lag models, have found empirical lag distributions associated with price variables that are not approximately geometric.

While these results cast doubt on the suitability of the adaptive expectations hypothesis, no firm conclusion can be reached because the studies were based on aggregate data. Factors other than expectations, such as inertia, affect the shape of lag distributions derived from aggregate data. Because of the difficulties in drawing conclusions from aggregate supply-response studies about the way in which farmers formulate their expectations, the present analysis has used data collected from individual farmers.

Data Collection

The present study reports the results of an economic game, similar to those previously employed with students (Fisher 1966, pp. 48–58), carried out with the cooperation of farm decision makers (a random sample of fifty-five operators from the Coonabarabran district of northwestern New South Wales, a major center of wheat growing in eastern Australia).

As part of a survey in which farmers were asked about their production decisions and their price expectations for the following season, the respondents were asked to participate in a game. Each farmer was given a series of ten prices in tabular form and told that these were for an agricultural commodity with which he would be unfamiliar. In addition, respondents were told that the prices were for an annual crop with only a limited export market.[1] Farmers were asked for the price they expected for the following year based on the information supplied. Finally, farmers were reminded that they routinely make decisions of this type and that for actual decisions, an incorrect expectation would lead to a loss of income.

Once respondents had decided on the expected value, they were told the actual value of the price series for that year. Given this new information, they were asked to formulate another expectation. After three expectations had been obtained, the farmers were shown a graph of the price series and asked whether they felt it would aid in decision making. The farmers were then asked for another three years' expectations, having the previous prices in both graphical and tabular forms. This procedure resulted in a total of 330 observations.

Characteristics of the Price Series

Inspection of the graph of the actual price series (figure 1), indicates that the series is nonstationary. Characteristics of the first differences of the series were examined by fitting first-, second-, and third-order autoregressive models. Because of the short length of the series, no attempt was made to fit more sophisticated models. The results from an ordinary least-squares regression suggested that the coefficient on the third-order lagged price variable was not significant. The best of three alternative descriptions of the series was the second-order autoregressive model given below.

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[1] The prices used were actual annual potato prices from the Sydney wholesale market for the financial years 1957–58 to 1972–73. No attempt was made to expose separate groups of respondents to different series of prices, because the size of the sample was limited.

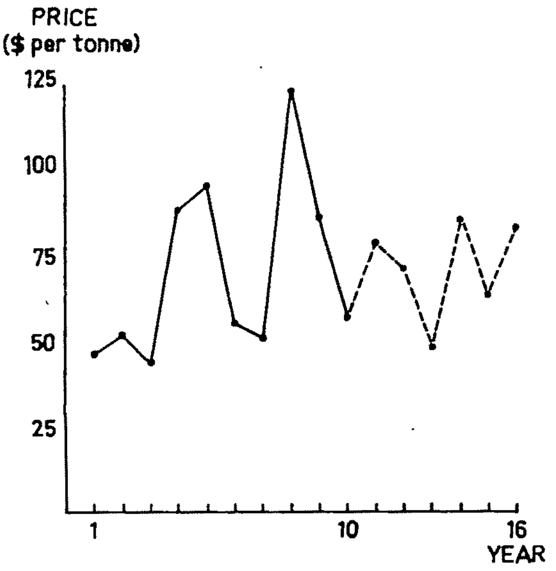

Figure 1. The actual price series used in the experiment

$$(A_t - A_{t-1}) = \underset{(0.76)}{5.73} - \underset{(-2.34)}{0.56}\,(A_{t-1} - A_{t-2}) - \underset{(-2.72)}{0.67}\,(A_{t-2} - A_{t-3}),$$

$$R^2 = 0.49,\ F = 4.87$$

The numbers in parentheses are t-statistics.

Formulation of Expectations

The expectations data were analyzed to determine which of six hypotheses about the formulation of price expectations best described the generated series. As mentioned above, a popular hypothesis employed in supply-response analysis is Nerlove's adaptive expectations hypothesis,

(1) $$P_t = P_{t-1} + \alpha_1 + \beta_1 (A_{t-1} - P_{t-1}),$$

where P_t is the expected price and A_t is the actual price. A related hypothesis considered was 'perverse' adaptive expectations,

(2) $$P_t = \alpha_2 + \beta_2 A_{t-1} + \beta_3 (A_{t-1} - P_{t-1}).$$

In the case of hypothesis (1) the variable P_t is positively related to P_{t-1}; whereas in the 'perverse' adaptive expectations model, the relationship is negative.

In his study of the formation of price expectations by businessmen, Turnovsky found that empirical evidence favored the extrapolative expectations hypothesis. The particular version of this hypothesis considered for the present analysis was

(3) $$P_t = \alpha_3 + A_{t-1} \{\beta_4 + \beta_5 [(A_{t-1} - A_{t-2})/A_{t-2}]\}.$$

An important concept introduced by Muth is the rationality of expectations. If expectations are generated by some predictive formula, the predictive scheme is rational only if the expectations and the realizations follow the same autoregression (Turnovsky, p. 1445). Because of the nature of the original series, the following hypothesis was formulated as a test for rationality:

(4) $$P_t = \alpha_4 + \beta_6 A_{t-1} + \beta_7 A_{t-2}.$$

A first-order autoregressive model, closely akin to (4), was also tested, i.e.,

(5) $$P_t = \alpha_5 + \beta_8 A_{t-1}.$$

Finally, during the survey, a number of farmers indicated that they found it difficult to formulate expectations and that the best strategy was to take an arithmetic average of the past values of the series. Consequently, the following three-year moving-average model was considered:

(6) $$P_t = \alpha_6 + \beta_9 [(A_{t-1} + A_{t-2} + A_{t-3})/3].$$

Additional Hypotheses

During the survey, the interviewer made a subjective assessment of the way in which the respondents made decisions. Respondents were then classified as either "traditional" or "entrepreneurial." Farmers subjectively classified as "traditional" were those who had maintained a reasonably fixed pattern of production and exhibited an unwillingness to try new crops and a lack of awareness of price changes and business opportunities. By contrast, farmers classified as "entrepreneurial" appeared innovative and showed a greater awareness of profitable alternatives. The two groups were delineated because it was felt that there may have been a difference in the way in which members from each group formulated their expectations. Both additive and multiplicative dummy variables were used to test this hypothesis in applying the expectations models to the sample data.

The relationships fitted were additionally extended by the use of dummy variables to account for the possible differences associated with the condition that respondents had been given a graph of the actual price series half-way through the game. In addition, it was thought possible that the farmers may have altered their responses as they became more familiar with the task. Additive and multiplicative dummy variables were also used to test whether the coefficients of the models had changed significantly from period to period.

To be consistent with the way in which the autoregression was estimated for the actual price series, all of the models were restated with $(P_t - P_{t-1})$ on the left-hand side.

Table 1. The Estimated Relationships between Actual and Expected Prices

	Dependent Variable ($P_t - P_{t-1}$)					
Independent Variables[a]	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Constant	3.10	−0.19	−1.43	−0.87	−0.90	−1.30
	(3.31)	(−0.17)	(−1.26)	(−0.71)	(−0.74)	(−0.78)
$(A_{t-1} - A_{t-2})$		−0.09	0.54	0.16	0.15	
		(−1.16)	(8.04)	(4.20)	(4.76)	
$(A_{t-2} - A_{t-3})$				0.01		
				(0.29)		
$(A_{t-1} - P_{t-1})$	0.65					
	(16.39)					
A^*_{t-1}			−0.08			
			(−6.46)			
$(A_{t-1} - P_{t-1})^*$		0.46				
		(8.08)				
MA^*_{t-1}						−0.06
						(−0.26)
R^2	0.50	0.43	0.20	0.08	0.08	0.00
F	268.80	81.75	33.91	11.36	22.70	0.07

Note: Numbers in parentheses are t-statistics.

[a] $A^*_{t-1} = \{A_{t-1}[(A_{t-1} - A_{t-2})/A_{t-2}] - A_{t-2}[(A_{t-2} - A_{t-3})/A_{t-3}]\}$; $(A_{t-1} - P_{t-1})^* = (A_{t-1} - P_{t-1} - A_{t-2} + P_{t-2})$;
$MA^*_{t-1} = [(A_{t-1} + A_{t-2} + A_{t-3})/3 - (A_{t-2} + A_{t-3} + A_{t-4})/3]$.
These variables are the result of expressing the original models in first-difference form.

The Results

The results for the equations fitted without the dummy variables are given in table 1. When equations containing both the additive and multiplicative dummies together were estimated, it was found that none of the coefficients on the dummy variables were significantly different from zero. From this, three conclusions may be drawn. First, the analysis could not detect differences in the way in which the two groups formulated their price expectations. However, the subjective nature of the original classification may explain this finding. Second, the results imply that the presentation of the price information in a graphical form did not influence the way in which the respondents developed their expectations. This result is of interest because 78% of the respondents said that a graphical presentation of the prices was helpful. Finally, there was no evidence to suggest that the coefficients had changed over time. In other words, it appears that the farmers formulated all their expectations in an identical way throughout the game.

The estimates presented in table 1 indicate that the most successful explanation of the generated expectations series was provided by the adaptive expectations hypothesis (1). No other model, apart from model (2), was able to explain more than 20% of the variation in the series. The "rational" expectations hypothesis (4) performed badly, even though a number of respondents claimed that they detected a distinct pattern in the actual price series. The results show that they apparently thought that the series was positively autocorrelated when, in fact, the autocorrelation was negative. However, it should be recognized that the rational expectations hypothesis followed from a simple approximation of the systematic movement in the actual price series.

The three-year moving-average model gave extremely poor results. This, together with the above findings, suggests that, while farmers may say that they formulate price expectations using a simple arithmetic average, it is more likely that they use a weighted average, even though they may not recognize this tendency.

In summarizing, the foregoing evidence suggests that the farmers surveyed base their price expectations on a weighted average of past prices, the weights declining exponentially over time. If this result is true for farmers in general, then it has important implications for the manner in which expectations should be specified for inclusion in supply-response models.

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Teaching Decision Making Under Risk and Uncertainty to Farmers

John Holt and Kim B. Anderson

There have been relatively few extension attempts to teach decision making under risk and uncertainty to farmers. The work of Black in incorporating probabilities into outlook work, and Kadlec's suggested farming strategies under uncertainty are notable exceptions. Undoubtedly there are some others.

This paper reports an analytical and educational approach for teaching farmers some modern decision-making techniques. Decision trees are the core of this approach because they take into account "the simplifying procedures people use in 'real life' decision making" (Gladwin, p. 881). Interactive computer routines and portable terminals make it possible to use farmers' own problems as teaching tools.

The analysis, whether or not to graze stocker cattle on wheat, embodies production and marketing risk for decisions involving both cattle and wheat. Depending on the time of year when the decision is made, the questions may be whether to plant wheat early or late; whether or not to buy or sell cattle, both in the fall and in the spring; or whether to graze all, none, or part of the wheat with stockers. The spring decisions about grazing all, none, or part of the wheat with stockers provide the examples in this paper.

The Delivery System

The intent was to develop a program for use on portable terminals so that farmers' own situations could be analyzed in conjunction with a single educational meeting of three hours or less. An interactive program was developed (Anderson and Holt) to consider three yield levels for cattle and wheat and three different price levels for each. The model calculates nine income levels (price times yield minus costs) for each alternative and uses subjective probabilities for prices and yields to calculate the joint probability for each income level. The output format, shown later, permits a comparison of alternatives based on expected values, income ranges, or on the probability of receiving a target income level.

An effective extension delivery system should be "close by and convenient" (Kolmer, p. 916). This means involving county extension professionals, who are on-site salesmen for local education programs. Their bread-and-butter tool is a single meeting, usually held at night, and oriented to a particular topic. One-night stands are decried in other contexts, but county professionals who use them know that meetings must be held near an important segment of their clientele.

Teaching Procedure

The objectives for a meeting were to show producers a systematic procedure for analyzing the stocker decision and to provide them a way explicitly to incorporate yield and price uncertainty into their decision making. Four such meetings were held with an attendance of 178 farmers. The audiences ranged in size from 12 to 99; the smallest was a cosmopolitan board of directors of a commodity association, the others were typical farmer audiences generated by county extension agents in rural counties.

An overview of past yield and price fluctuations for cattle and wheat illustrated the need for producers to include a range of decision outcomes in their analyses. Another introductory point was that different managers, because of personal preferences, quite logically could make different decisions even when faced with the same external conditions.

The logic of incorporating uncertainty into a decision was illustrated for a range of wheat incomes (table 1). Beginning with the likely variation in yields, the decision tree was developed a step at a time. Experiment station results modified by weather information provided the yield estimates shown on the tree.

A discussion of price projections followed the yield estimates. The dialogue surrounding the price branches of the tree proved to be an effective means of conveying outlook information to a production-oriented audience. As expected, farmers were considerably less comfortable with establishing both price levels and their probabilities than was the case with yields.

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Table 1. Expected Wheat Incomes, Considering a Range of Yields, Prices, and Their Probabilities

Yield (bu.)	Yield Probability (%)	Crop Price ($ per bu.)	Price Probability (%)	Crop Income ($ per acre)	Joint Probability (%)
		2.40	20	71.50	3.76
35	18.8	2.15	60	62.75	11.28
		1.90	20	54.00	3.76
		2.40	20	52.30	12.50
27	62.5	2.15	60	45.55	37.50
		1.90	20	38.80	12.50
		2.40	20	33.10	3.74
19	18.7	2.15	60	28.25	11.22
		1.90	20	23.60	3.74

Note: Expected value per acre = $45.57.

Calculating incomes was a prelude to explaining the joint probabilities, or likelihood, of obtaining those incomes. The incomes shown in table 1 are price times yield minus an arbitrary harvest cost of $12.50 per acre. This was the only cost deducted because this example considered the disposition of a crop that was already established.

Joint probabilities were calculated and explained as the "odds" or chances of obtaining the given incomes with the indicated yields, prices, and probabilities. Farmers were more comfortable with joint probabilities than expected. A total of 61 farmers completed evaluation forms. Thirty-nine of these, or 64%, felt that the joint probabilities were the "strongest point of the program." Only three respondents "didn't understand joint probabilities."

Farmer interest centered on the joint probabilities for the income ranges, but expected values were also used to compare incomes obtainable from the different alternatives. The concentration in the meeting was on the decision-making process more than on the expected values, however. As can be seen in table 1, the expected value ($45.57) is almost identical with the value ($45.55) which might have been obtained by using enterprise budgets.

This result, caused by the symmetry of this particular discrete distribution of yields and prices, made for easy acceptance of the procedure by producers and others familiar with budgeting. However, the discrete distribution does not afford explicit recognition of the variance or skewness of a particular distribution. Only a crude approximation could be obtained of, say, a skewed distribution by redefining the price and yield spreads and assigning a different set of probabilities to them and then repeating the analysis. The discrete distribution was assumed because of a lack of knowledge of the appropriate continuous distributions for future yields and prices, and because using it made possible the development of an interactive program simple enough and small enough for use on portable terminals.

The Data

The data required for analyzing stocker alternatives are in table 2. Any nonzero element in the matrix can be changed to suit the user. The first two rows pertain to wheat, and were the coefficients shown on the decision tree. Rows 3, 4, and 5 indicate the expected conditions for grazing. Probabilities in row 3 are for total stocker production which involves grazing days, daily gains, and stocking rates. Stocker prices and probabilities are in row 6. Wheat prices and yields, and stocker prices and gains, were assumed to be independent events. Row 7, the proportion of acres harvested, is used only in the routine that calculates returns to a mix of grazing and harvesting wheat. Although not shown, variable costs were also obtained for the various options and used in estimating returns above cost.

The relationship between wheat yields and grazing gains is difficult to quantify both because data are limited and because a "good" year for wheat yields may not provide "good" gains for cattle that graze that wheat. Based primarily on a survey by Walker and Plaxico, supplemented with correlations of grain and forage yield from limited experimental data, the rather tenuous assumption is made that wheat yields are directly linked to grazing yields.

The probabilities of grain yields and grazing days

Table 2. Data and Probabilities for Wheat and Stocker Grazing, North Central Oklahoma

	Data			Probabilities		
Item	Good	Fair	Poor	Good	Fair	Poor
1. Grain yield	35.00	27.00	19.00	0.188	0.625	0.187
2. Grain price	2.40	2.15	1.90	0.200	0.600	0.200
3. Grazing days	80.00	65.00	50.00	0.188	0.625	0.187
4. Average daily gains	2.00	1.75	1.50	0.000	0.000	0.000
5. Number stockers per acre	0.40	0.40	0.40	0.000	0.000	0.000
6. Stocker price-sell	45.00	41.00	37.50	0.300	0.500	0.200
7. Proportion of acres harvested	0.80	0.73	0.60	0.000	0.000	0.000

in table 2 are identical, but they can be, and occasionally have been, specified differently by various users. When either the harvest only or the total grazeout options were analyzed, the program utilized the probabilites in rows 1 and 3 independently. However, when a mix of harvesting and grazeout was desired, the program invoked the direct linkage assumption, and both grain yields and grazing gains were weighted by the probabilities associated with grazing gains (row 3).

Comparing Alternatives

Incomes in table 3 were from selling stockers in March and harvesting all the wheat. The first three columns repeat the results of the harvest only analysis of table 1. For the spring decision, net income per acre from selling fall stockers is known ($12.30), and it is added to wheat incomes to obtain the incomes per acre shown in the fourth column. Expected value per acre is the incomes per acre weighted by the probabilities, or $57.87 per acre.

The most complex analysis was a mix of grazeout and harvest (table 4). Eighty-one outcomes are possible when three yield levels and three prices are considered for both cattle and wheat. Thus, some simplification is necessary to retain the interpretational ease afforded by a tree with nine outcomes. Since grain yields are assumed directly correlated with grazing gains, the number of outcomes is reduced to twenty-seven. Deriving a weighted wheat price (the sum of probabilities times prices) permits a tree with nine outcomes. The weighted wheat price times wheat yields times percentage of acre harvested produces the "Value Grain" column in table 4. Stocker weights were calculated for the different gains and multiplied by the respective prices to get stocker incomes per head for the March to May period. Then stocker incomes from the fall ($12.30 per acre, $30.75 per head) were added to balance this internal transaction, and the resulting incomes per head were displayed to help farmers who think in those terms.[1] Partial budgeting logic dictates ignoring stocker incomes for the alternatives of selling or retaining fall steers, since they are the same for both. However, much farm planning relies on cash flows, so the option of listing them permits a measure of net incomes to be seen for the different alternatives. Incomes per acre are "Value Grain" added to per acre stocker returns.

Comparing the analysis in tables 3 and 4 indicates that, if expected profit-maximization were the goal,

[1] McCarl and his coauthors argue for the inclusion of data "which are not necessary to the solution of the problem, yet contribute to farmers' understanding of the output" (p. 24).

Table 3. Wheat Yields, Prices, Incomes, and Probabilities, North Central Oklahoma

	Volume (bu.)	Price ($ per bu.)	Crop Income ($ per acre)	Income ($ per acre)	Joint Probability (%)
Good yield, good price	35.0	2.40	71.50	83.80	3.76
Good yield, fair price	35.0	2.15	62.75	75.05	11.28
Good yield, poor price	35.0	1.90	54.00	66.30	3.76
Fair yield, good price	27.0	2.40	52.30	64.60	12.50
Fair yield, fair price	27.0	2.15	45.55	57.85	37.50
Fair yield, poor price	27.0	1.90	38.80	51.10	12.50
Poor yield, good price	19.0	2.40	33.10	45.40	3.74
Poor yield, fair price	19.0	2.15	28.35	40.65	11.22
Poor yield, poor price	19.0	1.90	23.60	35.90	3.74

Note: Expected value per acre = $57.87.

Table 4. Wheat and Stocker Incomes, Harvest and Grazeout Mixture, North Central Oklahoma

Gains Yield	Stocker Price	Value Grain ($ per acre)	Stocker Weight (lbs.)	Stocker Income ($ per head)	Income ($ per acre)	Joint Probability (%)
Good	Good	50.20	710	99.84	90.14	5.64
Good	Fair	50.20	710	71.58	78.83	9.40
Good	Poor	50.20	710	46.86	68.94	3.76
Fair	Good	33.25	664	80.03	65.26	18.75
Fair	Fair	33.25	664	53.62	54.70	31.25
Fair	Poor	33.25	664	30.50	45.45	12.50
Poor	Good	17.01	625	63.59	42.44	5.61
Poor	Fair	17.01	625	38.71	32.49	9.35
Poor	Poor	17.01	625	16.94	23.79	3.74

Note: Expected value per acre = $56.41; expected stocker weight = 665; expected stocker per acre = 0.4.

March stockers should be sold and all the grain should be harvested ($57.87 > $56.41). However, a decision maker who wanted to increase his chances of reaching an income goal, say $60 per acre, might decide to keep the stockers and graze out part of the wheat. Grazeout harvest would provide a 37.55% chance of making at least $60 per acre, whereas selling March stockers and harvesting wheat has a 31.3% chance of making that much income (adding the probabilities of the incomes greater than $60 gives these percentages).

Five common spring decision analyses, including those shown previously are summarized in table 5. They illustrate the diversity of opinions possible when uncertainty and different managerial objectives are considered. Rows 1 and 2 pertain to farmers who did not buy stockers in the fall, whereas options 3, 4, and 5 were open to farmers who had fall stockers.

Wheat only (row 1) might have been chosen by the farmer who had no fall stockers, and was not inclined to take the risk associated with purchasing stockers (−$50.65 in row 2). Despite some potential losses associated with purchasing stockers and grazing out wheat, row 2 offered the highest probability of being able to make at least $60 per acre for the farmer who had no fall stockers. Choosing the highest expected profit would indicate choosing row 3. Another farmer with a similar situation might opt for row 4, which had a higher probability of obtaining $60 income per acre, even though both the minimum income and the expected value were lower than row 3. A "plunger" who placed more weight on the highest possible income per acre might decide to keep his fall stockers, buy more, and graze the wheat out (row 5).

Thus, in one audience, all five situations could have been (and were) chosen by different farmers, based on a consideration of the riskiness of the alternatives weighed against the farmer's inherent risk preferences. A teaching format which includes risk permits one to retain the attention of the whole

Table 5. Expected Values, Income Ranges, and Probabilities of Making More Than $60 per Acre from Wheat and Stocker Alternatives, North Central Oklahoma

Row	Decision	Expected Value	Income Range	Probability of Incomes ≥ $60 per Acre
		$	$	%
1	Harvest wheat only	45.57	23.60 to 71.50	15.04
2	Purchase stockers and grazeout	21.92	−50.65 to 97.62	37.55
3	Sell fall stockers and harvest all wheat	57.87	35.90 to 83.80	31.3
4	Keep fall stockers and harvest some wheat	56.41	23.79 to 90.14	37.55
5	Keep fall stockers, purchase more, graze wheat out	40.06	−32.61 to 115.87	33.79

Note: In addition to those noted in the text, the assumptions were: 1.8 stockers per acre for the spring period; a 0.5% death loss of owned stockers; and a 1.0% death loss on purchased stockers.

audience by approximating their individual decision-making processes. It has been interesting to observe farmers defending their different choices, based on identical analyses.

Farmer's Problems

The diversity of opinions possible with the example data illustrates why farmers appreciated the chance to have their own (or very similar) situations analyzed. To begin eliciting farmers' data, table 2 was shown again, with a discussion of the differences between their local situation and the data shown. Then a situation was selected which the group would like analyzed. Normally, an individual, more vocal than the rest, agreed to provide the data for his situation.

Farmers' management "rules-of-thumb" were directly incorporated into the teaching process at this point. Wheat yields, stocking rates, grazing days, daily rates of gain, prices, and the way these relationships are combined in their own analytical processes all get an airing here. Debate about some of these relationships sometimes raged among farmers. From a teaching standpoint, the problem was to control the debate enough to keep the emphasis on the decision-making process. Repeating an analysis with a different farmer's viewpoints (or information) about markets or cattle gains sometimes dramatically altered the outcomes, and further illustrated the diversity of decisions possible in this uncertain environment.

As obtained, the data were entered on the portable terminal by one of the two teachers and by the time the discussion had died down, the results had been transferred to a transparency and shown immediately to the audience. Major arguments were "settled" by changing the debated coefficients or probabilities and repeating the analysis.

Concluding Remarks

A manager's central role is making choices among uncertain outcomes. In that role, he needs decision-making aids which permit him to incorporate uncertainty into his decision-making framework. The decision tree approach, coupled with interactive programs and portable computer terminals, is a tool that can help.

Programs such as this one, focusing on the decision-making process itself, and adding the treatment of yield and price uncertainty to farmers' "rules-of-thumb" procedures, can aid farmers as they make choices among uncertain outcomes and commit present resources to an unknowable future.

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Adjustments in a Farm Business in Response to an Energy Crisis

Robert Burton and R. G. Kline

Effects of the 1973 price increases by the Organization of Petroleum Exporting Countries (OPEC) and the boycott placed on the United States by the OPEC's Arab members awakened Americans to the reality that the United States depends on imported petroleum to maintain the present level of energy consumption. Awareness of this domestic energy gap has raised serious questions about the possible impacts of energy crisis conditions on United States agricultural production. Agricultural production in the United States depends on petroleum products not only for the liquid fuels used by farm machinery but also for the manufacture of pesticides and nitrogen fertilizer.

Previous Work

Studies by Pimentel, Heichel and Frink, and the Steinharts discuss agricultural energy uses in terms of a common denominator such as kilocalories. Batie, in response to a Heichel presentation, stressed the importance of our society's "value system" of inputs and outputs and observed that "farmers are attempting to maximize income, not energy output."

Vaughn, Hughes, and Smith have recently completed energy-related studies at Virginia Polytechnic Institute and State University, comparing energy requirements of no-tillage and conventional-tillage corn in Virginia. They found that "no-tillage offers potential energy savings as well as better labor efficiency with increased crop yields." Energy savings were due to less machinery use and related engine fuel use under the no-tillage system. In another study, Holter summarized the quantities of "major fossil fuel inputs" used in producing dairy feed. He concluded that "efficient handling of manure from the cow to the field and judicious use of manure nitrogen to spare chemical (manufactured) nitrogen offer the most significant potential for conservation of fossil fuel on most dairy farms."

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A segment of the energy problem to which this paper is directed is how a profit-oriented farmer should adjust his farm business in response to circumstances which might result from the present domestic energy gap. The need for this type of study has been expressed by Virginia Extension farm management specialists desiring answers for farmers who ask how they, in the short run, might adjust their farm businesses if an energy crisis occurs.

Two general circumstances which might force a farmer to make adjustments in his farm business are an increase in the prices of energy-related inputs relative to output price and prices of other inputs, or a decrease in the availability of energy-related inputs.

The overall objective here is to provide information concerning alternative management adjustments to an energy crisis. More specific objectives are to provide information about how a Grade A dairy farm operator might adjust crops grown and feed purchases in response to rising prices of energy-related inputs relative to prices of outputs and other inputs, or in response to circumstances of limited availability of energy inputs; and to compare the expected income, crops grown or purchased, and energy usage for crop production resulting from alternative technologies. Specific technological alternatives evaluated for a typical dairy farm are the effects of a liquid manure system compared with a solid manure system and the effects of conventional corn tillage compared with no tillage (no-till) corn production.

While comparisons are made of the short-run effects of energy crisis conditions when alternative technologies are used, the long-run question of which alternative should be adopted is not answered by this study.

Procedures

The research models were designed to represent typical Virginia Grade-A dairy farms (modal size 80–120 cows). The modelled farms have 100 cows, 290 acres of open land, 46 acres of productive level land suitable for continuous row crops using conventional tillage or no-till; 95 acres of less fertile and more sloping land, also suitable for continuous row crops with no-till production but limited to 32

acres annually with conventional tillage; 19 acres suitable for hay or pasture but not row crops; and 130 acres suitable for pasture only.

Upright silos with an unloader and distribution system with capacity for 1,100 tons, hay barn for 100 tons, and free-stall barn structure for 100 cows are considered typical. One farm situation is modelled to include a solid manure system and the other, a liquid manure system.

Adequate crop machinery is available to produce feed crops with various crop alternatives. Machinery requirements are slightly different as the no-till system requires a sod corn planter. Machinery operations used for conventional corn tillage are chisel plowing, once-over discing, fertilizing, planting with a conventional planter, applying herbicide, harvesting, and shredding stalks (for corn grain). Machinery operations used for no-till corn (or corn silage) production are application of herbicides to kill cover crop and weeds, corn fertilization, planting with a sod corn planter, insecticide application, corn harvest, and the seeding, fertilizing, and discing-in cover crop.

Procedures for harvesting, storing, and feeding were modelled the same for all situations.

Budgets

Two dairy budgets are developed, one with a solid manure system and the other with a liquid manure system, for a 100-cow Grade-A dairy producing 15,000 pounds of milk per cow per year. The feed inputs for cows are specified in terms of feed nutrients.

Budgets are developed for crops typical of the area and for both conventional and no-till corn grain and corn silage production.

In the budgets used for this study, an attempt is made to set fertilizer and pesticide use at levels which represent practices generally recommended by extension personnel at Virginia Polytechnic Institute and State University. Yields are set at levels considered to be typical for these practices.

In Virginia and other areas of the Southeast, annual precipitation is high and much of the land has steep slopes. Many farmers presently use no-till corn production. In Virginia no-till corn production gives profitable returns to higher applications of fertilizer than used in conventional corn production. The no-till corn production budgets have higher yields, higher quantities of fertilizer, higher quantities of pesticides, and fewer hours of tillage machinery per acre.

To explore the profitability of lower quantities of energy inputs, two budgets are developed for corn silage grown on continuous row crop land, one using no-till and the other using conventional corn tillage, where the amounts of nitrogen and pesticides are reduced by 67% and the yields are reduced by 40%.

Model

Four farm situations are analyzed: farms with *(a)* solid manure, conventional corn tillage; *(b)* solid manure, no-till corn production; *(c)* liquid manure, conventional corn tillage; *(d)* liquid manure, no-till corn production. Using linear programming (LP) models, combinations of feed crops and feed purchases are determined which maximize returns to fixed resources under the following assumptions: *(a)* 1976 prices for all inputs with no restrictions on available energy inputs, *(b)* increases of 25%, 50%, 75%, and 100% in energy input prices, and *(c)* reduction in available energy inputs by 20%, 40%, 60%, and 80%. For each 25% increase in energy input prices or for each 20% reduction in energy inputs available, it is assumed that price of purchased feed will increase 25%.

Results

The modelled farm using no-till corn production has higher returns than a farm using conventional tillage, and the modelled farm using a liquid manure system usually has higher returns than a farm using a solid manure system. An exception to the latter occurred when an 80% restriction of energy inputs limited crop production such that it was not possible to utilize all nitrogen produced by cows (table 1).

Noteworthy results are that a 40% reduction in available energy reduces returns to management more than a 40% increase in energy prices. A 100% increase in energy input prices results in management returns of $215 (no-till corn, liquid manure system) and −$4,916 (conventional-till corn, solid manure system), while a 60% reduction in available energy lowers management returns to −$8,590 (no-till corn, liquid manure system) and −$13,070 (conventional-till corn, solid manure system).

Crops

With 1976 energy input prices and no restrictions on energy inputs (initial situations), no-till corn production results in higher grain production and lower corn purchases than conventional corn tillage (table 2). This is largely due to the greater acreage available to corn production and slightly higher yields with the no-till system.

The most profitable cropping and feed purchase systems change only moderately in response to increased energy prices. Reductions in the availability of energy inputs, however, bring about major changes in the most profitable combinations. When the availability of fuel, pesticides, and nitrogen is reduced by 40%, grain production is reduced 45% (no-till) to 58% (conventional tillage), hay production increases, and corn purchases increase. With

Table 1. Returns to Management on Hundred-Cow Dairy Farms, Initial Situation, Increased Prices of Energy Inputs, and Decreased Supply of Energy Inputs: No-Till and Conventional Corn Production, Solid and Liquid Manure Systems

Percentage of Energy Change	No-Till Production of Corn and Corn Silage: Solid Type Manure System	No-Till Production of Corn and Corn Silage: Liquid Type Manure System	Conventional Tillage of Corn and Corn Silage: Solid Type Manure System	Conventional Tillage of Corn and Corn Silage: Liquid Type Manure System
	($)			
Initial situation[a]	23,393	24,818	21,453	22,878
Increased energy prices[a]				
25	16,958	18,629	14,513	16,184
50	10,523	12,440	7,978	9,895
75	4,139	6,302	1,443	3,606
100	−2,194	215	−4,916	−2,507
Reduction in energy supply[a]				
20	18,388	19,813	15,304	16,729
40	9,065	10,490	6,107	7,532
60	−10,015	−8,590	−13,070	−11,645
80	−38,124	−37,879[b]	−40,037	−40,082[b]

[a] Prices of energy inputs in the initial model were considered to be at the 1976 level with no restrictions on supply. Prices were increased and supply reduced for gasoline, liquid petroleum gas, diesel fuel, atrazine, paraquat, furadan, sevin, and nitrogen (also purchased feed).
[b] In this situation excess nitrogen was furnished by manure system.

more than 60% reductions in available energy, dairy feeding tends to become restricted largely to pasture and purchased feed.

There are no differences between the two manure systems in the optimum combinations of crops.

Corn silage alternatives with 67% less nitrogen, atrazine, paraquat, and furadan inputs per acre and 40% lower yields than standard alternatives are not included in any optimum cropping system.

Energy Use

Modelled farms using no-till corn production utilize more pesticides, purchased nitrogen, and usually more liquid fuels than farms using conventional tillage. Only when energy prices increase do farms using no-till corn production utilize less liquid fuel than the conventional system. Farms with solid manure systems purchase more nitrogen inputs than farms using the liquid manure system under both no-till and conventional corn production systems (table 3).

Except for use of pesticides by farms using no-till corn production and use of nitrogen by farms using conventional corn tillage, it is not profitable to decrease use of energy inputs when prices of energy inputs, as well as the prices of purchased feeds, are increased proportionately. If prices of purchased feeds are not increased as the prices of energy inputs are increased 100% from the initial solution, energy uses change as follows: *(a)* with no-till corn production, liquid fuels −1%, pesticides +57%, purchased nitrogen −100% and total purchased energy inputs −57%; *(b)* with conventional corn tillage, liquid fuels +23%, pesticides 0%, purchased nitrogen −65% and total purchased energy inputs −22%.

Discussion

The results of the present research indicate that as compared to conventional corn tillage, no-tillage corn production results in higher net returns to the modelled dairy farmers but also higher use of energy inputs. Farmers employing no-till corn production use more energy per farm and per dollar net returns than is used by farmers employing conventional corn tillage. Farms with no-till corn production have higher returns than farms with conventional corn systems because with the former system higher corn grain and corn silage yields are achieved and more importantly because more acres of sloping land can be used annually for growing corn. Although the no-till corn system requires less engine fuel per acre for land preparation, the no-till system uses more energy inputs in the form of nitrogen fertilizer and pesticides.

The results of this study do not conflict with the findings of Vaughn, Hughes, and Smith concerning engine fuel saving with no-till row crop production. The results do raise a question concerning total energy requirements of fuel, pesticides, and nitrogen fertilizer of no-till as compared to conventional

Table 2. Crops Produced and Feeds Purchased on Hundred-Cow Dairy Farms, Initial Situation, Increased Prices of Energy Inputs, and Decreased Supply of Energy Inputs: No-Till and Conventional Corn Production

	Crop grown						Feeds purchased		
Items[a] (%)	Wheat grain (Bu.)	Corn grain (Bu.)	Corn silage (Ton)	Other silage (Ton)	Hay (Ton)	Pasture (Acres)	Soybean-meal (Cwt.)	Corn (Bu.)	Alfalfa hay (Ton)
					Initial Situation				
NT	—	5,790	918	256	46	130	1,668	—	—
CT	1,869	—	922	252	46	130	1,571	4,002	—
					Energy price increase				
NT									
25	Same as initial situation								
50	Same as initial situation								
75	—	6,169	785	365	46	130	1,606	—	—
100	—	6,276	748	397	46	130	1,589	—	—
CT									
25	—	3,588	427	505	46	130	842	5,410	—
50	Same as 25% price increase								
75	Same as 25% price increase								
100	—	3,821	368	555	46	130	820	5,329	—
					Reduction in energy supply				
NT									
20	28	5,287	765	333	46	130	1,409	1,476	—
40	409	2,707	843	—	187	131	1,251	4,113	—
60	—	2,194	546	—	137	191	822	6,563	110
80	—	1,189	273	—	47	247	409	8,985	255
CT									
20	1,507	694	826	301	46	130	1,430	4,274	—
40	785	20	1,015	—	111	155	1,504	5,184	—
60	—	2,157	528	—	94	199	796	6,671	154
80	—	1,164	267	—	25	251	400	9,027	276

[a] NT is no-till production of corn and corn silage; CT is conventional tillage of corn and corn silage.

corn production. Higher returns with the liquid manure system, compared to the solid manure system, emphasize conclusions made by Holter.

When energy prices are increased 100%, returns to management for dairy farms using alternative technologies range from \$215 to −\$4,916. When energy quantities are restricted 60%, returns to management for farms using alternative technologies range from −\$8,590 to −\$13,070. Again, farms with no-till corn production have more profitable operations and use less engine fuel energy but use more total energy inputs per acre and per dollar returns than farms using conventional corn tillage. Both the more profitable no-till system of corn production and the severe income reductions associated with energy input rationing will cause difficult conflicts for policy makers who attempt to deal with problems of low farm income and energy conservation.

This study develops conclusions only for a short run. In the longer run milk prices likely would increase, and alternatives for fossil fuel inputs probably would be developed. These and macro effects of indicated micro results would likely change many of the existing parameters. The effects on energy consumption of alternative methods of harvesting, preserving, storing, and feeding crops were not considered in this study. Although the research reported is oriented to 100-cow Grade-A dairy farms in Virginia, many of the implications have applicability to larger or smaller dairy farms, to other types of livestock farming in Virginia, and to areas with similar precipitation, topography, and soil conditions.

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Table 3. Energy Inputs Used in Crop Production on Hundred-Cow Dairy Farms, Initial Situation, Increased Prices of Energy Inputs, and Decreased Supply of Energy Inputs: No-Till and Conventional Corn Production, Solid and Liquid Manure Systems

Percentages of Change	No-Till Production of Corn and Corn Silage (1000 kilocalories used)				Conventional Tillage of Corn and Corn Silage (1000 kilocalories used)			
	Liquid Fuels[a]	Pesticides[a]	Purchased Nitrogen[a]	Total	Liquid Fuels	Pesticides	Purchased Nitrogen[a]	Total
				Initial Situation				
	101,962	5,742	126,994	234,698	75,884	2,431	88,260	166,575
				Energy Price Increase				
25	101,962	5,742	126,994	234,698	111,841	2,431	46,611	160,883
50	101,962	5,742	126,994	234,698	111,841	2,431	46,611	160,883
75	107,581	5,702	133,806	247,090	111,841	2,431	46,611	160,883
100	109,178	5,691	135,743	250,613	115,273	2,431	50,526	168,231
				Reduction in Energy Supply				
20	103,908[b]	5,079	104,967	213,954	82,842	2,431	80,201	165,473
40	77,058	3,996	60,178	141,232	58,260	2,570	51,171	112,002
60	53,724	3,233	15,211	72,169	53,500	2,457	12,300	68,256
80	27,420	2,451	—	29,870	27,267	2,063	—	29,329

Note: Nitrogen purchased is given for the liquid manure system; the use of a solid manure system increases nitrogen purchase by 3,516 pounds (29,534 1000 kilocalories).

[a] Liquid fuels include gasoline, diesel fuel, liquid petroleum gas. Pesticides include atrazine, paraquat, furadan, sevin, and 2,4,D.

[b] This increase in liquid fuels was possible because the quantity restrictions on the energy inputs were initially set at levels slightly higher than the level of the manure system/corn tillage alternative with the highest level of use. Thus, when no-till corn production was used the level of the initial diesel fuel restriction and crop adjustments were such that diesel fuel use increased with a 20% reduction in quantities available of all the energy inputs.

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The Tradeoff Between Expected Return and Risk Among Cornbelt Farmers

Lars Brink and Bruce McCarl

The inclusion of risk in farm-planning models has been the subject of many theoretical discussions, often with the conclusion that explicit risk consideration features are desirable. Operational linear programming-based farm-planning models are maintained by both universities and businesses. These operational farm-planning models do not generally include explicit risk consideration. The general objective of this paper is to investigate whether or not risk should be introduced explicitly in an operational farm-planning model.

Crop-planning models are used for at least three purposes: *(a)* to help farmers plan acreages, *(b)* to help farmers budget returns to investments, and *(c)* to help policy makers predict farmer responses to policy decisions. For all these purposes it is important that the model predict acreage distribution among crops accurately. The primary objective of this paper is to determine if risk consideration in the model helps predict actual farmer behavior in terms of crop acreages chosen.

We consider only activity return risk here. This makes it possible to use a portfolio choice model (Markowitz, Freund), which utilizes a tradeoff between a return expectation and a measure of risk, and which contrasts with the usual linear programming farm-planning model that maximizes return without explicit consideration of risk.

The operational farm-planning model considered here is the Purdue Top Farmer Cropping model (McCarl et al.). This model is used routinely with approximately 500 farmers per year in groups ranging from 20 to 200. Because of the size of these groups, the explicit inclusion of risk in the model must not require an intensive procedure involving each individual farmer. Thus, a secondary objective of this paper is to observe the diversity between farmers in terms of their trade-off between return expectation and risk. If this diversity is small, the simple approach of a common default value for the trade-off may be justified in routine use of the model.

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In order to meet these objectives, a linear programming portfolio choice model is developed. The model is specified for thirty-eight Cornbelt farmers, using their individual farm data and a common measure of risk. The measure of risk is negative deviation from a return expectation. Experiments are then carried out to try to explain farmer behavior through the inclusion of risk aversion. The results are presented for the group and for individuals. The final section of the paper presents conclusions and limitations.

A Farm Planning Model Incorporating Risk

The Purdue Top Farmer Cropping model (a linear programming type) determines "optimum" acreages and schedules for land preparation, planting, and harvesting of four crops: corn, soybeans, wheat, and double-crop soybeans. With a return maximizing objective, the model has 112 rows and 178 columns. When explicitly including risk in the model, we chose a linear programming technique in order to keep the model practical for extension purposes. Specifically, a technique based on Hazell's 1971 formulation was chosen, due to the ease with which it could be implemented. This risk model is similar to the portfolio choice-mean variance models which assume normality of outcomes or quadratic utility. The basic risk formulation is:

(1) maximize $C'X - \epsilon K \mathbf{L}\mathbf{d}$,
subject to $AX \leq B$,
$DX + I\mathbf{d} \geq 0$,
and
$X, \mathbf{d} \geq 0$,

where X, A, B, and C represent activity levels, resource uses, resource availabilities, and gross margin expectations.

This model contains an actual gross margin observation in each of s years for each risky activity in X. The difference between the gross margin observed and the gross margin expectation in a particular year is an element of D, the deviation matrix. The vector, $\mathbf{d}$, represents yearly total negative deviations summed over all risky activities. The elements of $\mathbf{d}$ are summed over s years by $\mathbf{L}$, a row vector of ones, to give a measure of summed total negative deviation over all years. This sum is transformed into an estimate of standard deviation by

multiplication by the constant K.[1] The trade-off between gross margin expectation and risk is represented by the risk aversion coefficient, ϵ. Parameterization of ϵ gives the efficient set of plans. An $s \times s$ identity matrix is shown as I.

The conversion from total negative deviation to standard deviation is done here to facilitate comparison of the ϵ coefficient with the coefficients found in other studies employing similar objective functions (such as Hazell 1974, Simmons and Pomareda, and Nieuwoudt, Bullock, Mathia). Exact comparability requires that the total negative deviation be half of the total absolute deviation. This may or may not be the case, depending on the expectation model used to derive gross margin deviations.

Data

The linear programming model with explicit consideration of risk was specified for each of thirty-eight crop farmers who used the Purdue Top Farmer Cropping model in July 1975. These farmers were generally large Cornbelt cash grain farmers who paid to attend the Purdue workshop. In the workshop, each farmer indicated his current allocation of land to crops (the "present" plan), price and yield expectations, production costs, machinery performance rates, and resource availabilities. The acreage farmed ranged from 305 to 3,600 acres, with a mean of 1,144 acres (median 867 acres). The mean yields of corn and soybeans were 125 and 38 bushels per acre, respectively.

Ideally, a deviation matrix, D, should have been formed for each individual farmer, but this was not possible for practical reasons. Thus, although each farmer's individual July 1975 data were used to specify the nonrisk portion (C, A, and B) of his model, the risk portion, D, was specified from data that were assumed to be common to all the thirty-eight farmers. The D matrix was obtained from gross margin outcomes synthesized from historical data. Gross margin here is crop price times yield minus variable costs of production. A twenty-four-year (1951–74) series of gross margins was synthesized for central Indiana for all crops over all production possibilities from agronomic experiments, discussions with extension personnel, and local price statistics (Brink). Using the U.S. Department of Agriculture parity index, the historical gross margins were inflated to the 1975 level.

Formation of the deviation matrix also required the development of gross margin expectations. The mean of the series of gross margins is often used as the expectation. Given the relatively long series of gross margins, the mean appeared to be an unrealistic measure of farmer expectation (due to farmer age, foresight, consideration of current trends, etc.). Thus, a five-year moving average was chosen as the gross margin expectation.[2]

Table 1. Matrix of Correlation Coefficients

	Corn	Soybeans	Wheat	Double Crop Soybeans
Corn	1	.70	.51	.51
Soybeans		1	.36	.53
Wheat			1	.36
Double crop soybeans				1

Risk, for corn, soybeans, and wheat (using a typical production activity) is lower when measured as the gross margin deviation from a five-year moving average expectation than when measured from the mean of the twenty-four year series. The reverse was true in the case of double-crop soybeans. The gross margin deviations show that corn and double-crop soybeans were the two riskiest enterprises. The gross margin correlation was positive between all four crops, with the highest correlation between corn and soybeans (table 1). A linear regression on time was run for the series of gross margin outcomes, but no significant upward trend was found. Apparently, the use of the parity index to express all gross margins in 1975 dollar values removes the upward trend often associated with a time series of gross margins per acre.

Experiments

A set of farm plans was derived for each of the thirty-eight farmers. The set contained twenty plans, obtained by parameterizing the risk-aversion coefficient, ϵ, in twenty steps in the range of 0 to 1.95. (Higher values were used; however, they resulted in unplanted acreages.) The risk-aversion coefficient could then be obtained in a crude way, utilizing the information supplied by the farmer in indicating his "present" plan. A farmer's risk-aversion coefficient was taken to be that value of the parameterized coefficient which minimized the difference between the associated plan in the set and the "present" plan. The difference was measured in terms of the total absolute deviation in acreage of each of the four crops (corn, soybeans, wheat, and double-crop soybeans), and in terms of the summed total absolute deviation of all four crops. Attributing all of the difference between the plans to risk would embody strong assumptions because the "present" plan will also be affected by

[1] K equals $\frac{2}{s}\sqrt{\frac{s \cdot \Pi}{2(s-1)}}$ (for $s = 24$, $K = 0.10669$). The factors outside the square root sign convert total negative deviation to mean absolute deviation, and the square root converts the mean absolute deviation to an estimate of the standard deviation (see, e.g., Simmons and Pomareda).

[2] Thus, for 1972, the expectation was an average of 1967–71 gross margins. For the first five years, a simple average was used.

such things as a farmer's other operations, such as livestock, or forward commitments, such as contracts for future delivery. This study, in fact, utilizes the null hypothesis that risk aversion makes no difference. The alternative hypothesis is that part of the difference is explainable by risk aversion.

To test whether risk aversion had any effect on the whole group of thirty-eight farm plans, an analysis of variance was carried out. The twenty parametric values of the risk-aversion coefficient were regarded as treatments, and the individual farmers were repeated subjects. Thus, a randomized complete block design was obtained. The effects of the risk-aversion treatments were the acreage differences between the "present" plan and the plan from a model run with a particular risk-aversion coefficient. The analysis of variance was performed with the null hypothesis of no significant difference among the treatment effects. Thus, if the null hypothesis is rejected, there are significant differences among the acreage differences resulting from various risk-aversion coefficients. This is a manifestation of an efficient frontier situation, involving a trade-off between risk and other characteristics of farm plans. If the hypothesis was rejected, then the least significant difference test (Newman-Keuls test) was applied to the twenty treatment means (acreage differences). This made it possible to find acreages that were statistically different from the smallest acreage difference exhibited between the "present" and optimum plans and thus to gain insight into the effects of risk-aversion coefficients of various magnitudes. This approach was used with acreage differences in each crop and with the total acreage difference for all crops.

Results

The null hypothesis of no difference in effects of different risk-aversion coefficients was rejected at the .01 level. This happened for each of the four crops and for the aggregate crop measure. For corn, soybeans, and the aggregate crop measure, the closest acreage prediction was obtained with a risk-aversion coefficient of zero, i.e., the profit maximizing, risk-neutral criterion minimized the difference between "present" plan and the derived plan. On the other hand, the treatment effect of a coefficient of zero was not significantly different from the treatment effect of a coefficient of .08. The effects of these two treatments were significantly smaller than any other treatment effect (risk-aversion coefficient).

Some doubt was cast on this result by the observation that, in twenty-five of the thirty-eight cases, the plan derived for every value of the coefficient (including zero) included less corn and more soybeans than the "present" plan. Thus, the "present" mix of corn and soybeans could never be achieved in the course of the parametric derivations of plans. This suggested an erroneous model specification.

An investigation of this phenomenon showed that it may have been due to the nature of the price expectations used. The prices expected by the farmers (in July) had a mean of \$2.29 per bushel for corn and \$5.15 per bushel for soybeans. This gave a ratio of 1 to 2.31. During one week of the planting season (in May) the local bid prices averaged \$2.58 per bushel and \$5.05 per bushel (a ratio of 1 to 1.96). The prices indicated by the farmers in July thus favored soybean planting rather than corn planting as compared to the prices in the planting season. This discrepancy in price expectations was removed by performing the set of experiments again with farmers' price expectations adjusted so that the expected price of soybeans was 2.05 times the expected price of corn. This represented the average soybean/corn price ratio in the planting season of 1975.

Given this planting time ratio of corn to soybean prices, all farmer price expectations were adjusted and the complete experiment was then rerun. The results involving crop acreage mix were such that only nine of the thirty-eight farmers had corn acreage outside the derived ranges. The null hypothesis of no difference in predictive ability when using different risk-aversion coefficients was again rejected at the .01 level.[3] The observed aggregate acreage derivation between the "present" plan and the derived plan, averaged over the group of thirty-eight farmers, is displayed in figure 1 for the various risk-aversion coefficients.[4]

The results showed the best fit occurred at a risk-aversion coefficient of .23 where the deviation was 442 acres. This deviation compares with an average farm size of 1144 acres and a range of possible values for the deviation from zero to twice the average farm size. Applying the least significant difference test showed no significant difference in the results for risk-aversion coefficients from zero (deviation 535 acres) to .62 (deviation 556 acres). Thus the best fit was not significantly different from the risk-neutral plan and yielded an improvement of 92 acres in the aggregate explanatory power of the model. Considerable variation in acreage was observed, however, as ϵ became large, with a 950-acre deviation at 1.95.

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[3] The hypothesis was not rejected for double crop soybeans; however, it was rejected for the other individual crops and for the aggregate acreage measure.

[4] A formula for this difference is

$$TA_k = \sum_{j=1}^{38}\left(\sum_{i=1}^{4} |PA_{ijk} - PP_{ij}| \right) \Big/ 38,$$

where PA_{ijk} is the model result on acreage of crop i for farmer j under risk aversion level k, PP_{ij} is the present plan acreage of crop i for farmer j. The value of this result ranges from zero to twice the farm size.

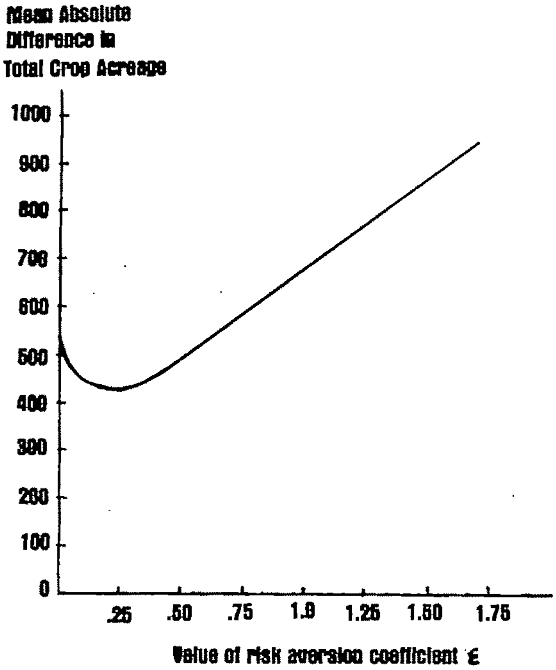

Figure 1. Correspondence between "present" and predicted crop mix

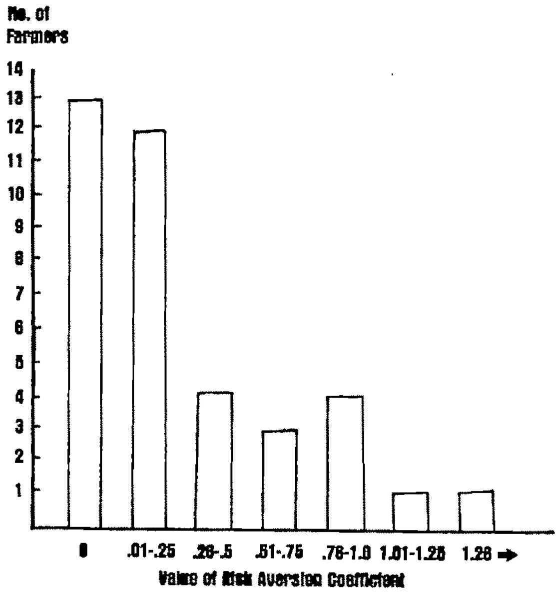

Figure 2. Numbers of farmers by value of risk aversion coefficient

An estimate of each individual farmer's risk-aversion coefficient was obtained by finding that coefficient for which the aggregate acreage difference was the smallest. Best fit was not always obtained for a unique ϵ value. In a case where several ϵ values gave the same acreage difference, the lowest value was chosen if there was no difference in the acreage mix of various crops. If the mix of acreage between crops varies with the ϵ value, but the total acreage difference between "present" and derived plan was the same, the median ϵ value was chosen. Figure 2 is a histogram showing the number of farmers, out of the group of thirty-eight farmers, with the individually estimated risk-aversion coefficient grouped in various intervals. The majority, twenty-five farmers, had coefficients that were zero or less than 0.25. On the other hand, the estimated coefficients ranged as high as above 1.25, which indicates a substantial diversity among individuals.

An alternative measure of the difference in plans involves total return to farming (income). In a subgroup of twelve one-man farms out of the group of thirty-eight, difference between plans was measured in terms of return to labor and management. The analysis, in this case, also indicated a substantial diversity among individual risk-aversion coefficients (Brink).

Concluding Comments

An attempt was made to determine whether explicit risk-aversion should be included in an operational farm planning model. The research was done by deriving risk-aversion coefficients for thirty-eight farms individually and as a group. The risk-aversion coefficient was derived by minimizing the difference between their actual behavior and the model results.

The decision criterion used measured risk as total negative deviation from an expectation. The arbitrariness with which such risk measures have to be postulated raises questions about how farmers perceive risk and what measure of risk is appropriate in this type of farm planning application. Specifically, is risk adequately measured by deviation from expectations and how are expectations formed? Another important question is whether the linear utility function as used here is the proper form.

The method of estimating the individual risk-aversion coefficient was based on actual farmer data. Previous attempts principally have involved facing farmers with hypothetical questions (such as Scandizzo and Dillon, or Lin, Dean, Moore). Scandizzo and Dillon mention that difficulties are encountered in estimating risk aversion with this approach. Although it appears desirable that risk studies be done using actual farmer behavior rather than hypothetical behavior, the difficulties encountered here with price expectations, for example, may indicate why gaming approaches have been preferred.

The risk aversion found among thirty-eight individual Cornbelt farmers here is generally much lower than that found in sectoral studies, such as Hazell (1974), Simmons and Pomareda, and Nieuwoudt, Bullock, and Mathia. The risk-aversion coefficient estimated in those studies has ranged from 0.5 to 2.0. It must be recognized, of course, that these coefficients are not exactly comparable because of the differences in risk modeling (i.e.,

calculation of deviations), crop coverage, and aggregation. The difference in order of magnitude of the risk-aversion coefficient between this study and the previous studies, however, is too large to be ignored. The conclusion is that risk aversion may play a smaller role in Cornbelt crop farming than in many other types of farming.

The result of this exploration of the risk attitudes of individual farmers indicates that risk-aversion is not, in general, an important factor in choice of crop acreages in the group studied. This conclusion is supported by the difficulty in explaining observed farmer crop-acreage allocations by risk aversion. Further, a large diversity of individual risk-aversion coefficients was found. The implication is that the risk feature employed in this exploration should not be implemented in the current planning model. The efforts to measure risk and risk aversion appear to be very great compared to the gains in ability of the model to produce plans that are consistent with the behavior of the decision maker (figure 1).

The conclusions of this study may be influenced by several key assumptions or omissions. Different expectation models would generate different results. Marketing alternatives have not been fully portrayed, and their inclusion might greatly alter risk characteristics. Finally, perhaps the farmers themselves discounted the price and yield expectations (although efforts were made by the researchers to avoid this). It is suggested that, instead of formally changing the crop-planning model, discounting of expectations be encouraged for those farmers to whom risk is important.

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Schooling and the Agricultural Minimum Wage

H. F. Gallasch, Jr. and Bruce L. Gardner

The papers of Gallasch, Gardner, and Lianos, among others, suggest that extension of the Fair Labor Standards Act in 1967 to cover hired farm workers increased farm wages and reduced employment. While the magnitudes of these effects are uncertain, the direction of impact seems clear. Studies of minimum wages in the general economy indicate that skills of workers are an important determinant of the impact of minimum wages, finding a disproportionate effect on young and unskilled workers (Welch). Schooling, as a measure of skills, was incorporated in an econometric model of the farm labor market by Gisser. He found that increased schooling had an output effect, attributed to an increase in the productivity of farm labor, but that this effect was outweighed by a migration effect which decreased farm labor supply. Consequently, schooling had a net effect of increasing farm wages and reducing farm employment.

This paper considers the role of schooling in modifying the effect of the agricultural minimum wage on farm workers. We attempt to integrate the independent effect of schooling with its effect via interaction with the minimum wage. Following a brief discussion of the theoretical framework used, the data and empirical results are presented. Finally, some policy implications are suggested.

The Farm Labor Market Model

Schuh (1962), Gisser, and Wallace and Hoover developed empirical supply-demand models of the hired farm labor market. Gallasch, building upon the work of these authors, developed a structural supply-demand model which accounted for the potential excess supply of hired farm labor brought about by imposition of the agricultural minimum wage. Though discussed in detail elsewhere (Gallasch), this model and our modifications will be described briefly.

The model consists of four equations—supply, demand, excess supply, and market equilibrium—which interact to determine the values of four endogenous variables: quantity supplied, quantity demanded, the wage rate, and excess supply. The wage rate is considered endogenous because a substantial portion of workers either are not covered or have higher wages than the minimum and because wages in kind may leave room for wage flexibility in the presence of the minimums.

The equation for labor demand, Q_D, contains variables representing the average per hour wage for hired farm workers, W; the supply of the substitute factors, land in farms, $LAND$, and expenditures on nonlabor inputs, XK; technical change, measured by lagged expenditures on agricultural experiment station research and extension work, REX; the level of schooling, mean years of schooling completed by farm laborers aged 16 and older, S; median age of farm laborers, AGE; and the minimum wage variable, $MINA$.

In the supply function, Q_S, the exogenous variables are: average per hour farm wage, W; the alternative, nonfarm wage, WN; level of schooling, S; and age of farm workers, AGE.

The supply and demand functions, in general form, are:

$$(1)\quad Q_D = D(W, XK, LAND, REX, S, AGE)$$
$$(2)\quad Q_S = S(W, WN, S, AGE)$$
$$(3)\quad ES = \gamma\, MINA$$
$$(4)\quad Q_D + ES = Q_S.$$

Equation (3) represents the excess supply of labor in the market when the minimum wage is effective (ES). When any portion of the market is covered by an effective minimum, some excess supply of labor will exist. Equation (4) is the equilibrium condition which completes the model.

Simultaneous solution of this model provides reduced form equations for each of the four endogenous variables. However, as discussed by Gallasch, only average wage and actual employment are observed, so that only two reduced-form equations can be estimated. These reduced-form equations provide an appropriate framework for analysis of the minimum wage when coverage is not complete and the minimum is not always effective.

The idea that schooling influences the impact of the minimum wage is introduced by means of a cross-product interaction term, $S{*}MINA$, in the reduced-form equations for both employment and the wage rate. Apart from this interaction term, the estimated equations are linear.

The Data

The model is estimated using state data. The endogenous variables, hired farm labor wage and employment, are obtained from the U.S. Department

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of Agriculture (1960 and 1970) and U.S. Department of Commerce (1961–62 and 1971–72), respectively. The wage variable is each state's annual average of hourly real wage rates without room and board. The employment of hired farm workers is the number of farm laborers in the state. Unavailability of hours-worked data prior to 1965 precluded its use.

The variable *XK*, which is a proxy for nonlabor inputs, represents expenditures (in billions of 1958 dollars) on material inputs and was obtained from the USDA (1972). Ideally, the nonlabor factor supply functions should be held constant. Assuming material inputs are produced at constant cost in the long run, a variable representing prices is preferable to expenditures in considering long-run adjustments. Expenditures are endogenous, so that the coefficient of this variable is biased in both the wage and employment equations. Nonetheless, in the absence of state price data, expenditures should be useful in holding conditions constant in a state's nonlabor factor markets.

Exogenous shifts in the demand for farm labor as a result of technical progress are potentially important. However, a variable which measured the actual use of new production techniques would be inappropriate due to its being endogenous. A reduction in farm employment when the minimum wage is introduced would of course tend to be associated with increased use of alternative inputs. But this association would not mean that the adoption of the new inputs caused the employment reduction. Technical progress in the production of material inputs used in agriculture is appropriately captured by the prices of these inputs assuming they are produced in constant cost industries. Our proxy, which attempts to measure the exogenous influences of innovation in productive techniques given input prices, is an adaptation of that suggested by Griliches and by Wallace and Hoover. This variable is the sum of fiscal year state expenditures (in millions of 1958 dollars) on experiment station research and expenditures on cooperative agricultural extension work. The former expenditures are from the USDA (1961–72) and the latter are from unpublished data provided by the USDA's Federal Extension Service.

The schooling variable, *S*, is available only for census years. This restricts the regression analysis to two cross sections of states, one for 1960 and the other for 1970. *S* is an estimate of mean years of schooling completed by farm laborers aged 16 and older (U.S. Department of Commerce, 1971–72). For 1960, the census schooling data are available by region (South and non-South) for farm laborers as an occupational class, but by state only for all rural-farm residents. The state/regional relationship for the rural-farm category is used to estimate state data for the farm laborer category. For example, Alabama mean schooling for rural-farm residents in 1960 is divided by the mean for the southern region. This ratio is then multiplied by the 1960 regional mean for farm laborers in 1960 to get an estimate of the mean schooling of Alabama farm laborers. For 1970, the census provides state schooling data for the occupational as well as the residential classification. The schooling data are not adjusted for quality. Since the quality of schooling was probably increasing, and is probably higher where the level of schooling is higher, failure to measure quality probably results in understating the schooling effect.

The age variable, *AGE*, plays a role on both the supply and demand sides of the farm labor market. It shifts demand because the productivity of workers varies with age and supply because the costs and returns to occupational migration vary with age. *AGE* is measured as the median age of farm laborers (U.S. Department of Commerce, 1961–62 and 1971–72).

The alternative wage, *WN*, is measured by the annual average hourly earnings of production workers on manufacturing payrolls (U.S. Department of Labor). In order to adjust for the probability of not finding employment in the nonfarm sector, the nonfarm wage is multiplied by one minus the state's unemployment rate. The resulting variable is a measure of the expected value of the nonfarm opportunity wage. There is question as to the appropriate nonfarm wage rate. Ideally, one would want to measure the alternative wage by a weighted average of wage rates in each state's nonfarm industries, the weights being the fraction of farm workers for whom each industry is the primary nonfarm alternative to farm employment. In the absence of such data, we felt that wages of production workers in manufacturing were sufficiently broad in scope and highly enough correlated with wages in other industries to which farm workers move to serve as an overall indicator of alternative wages.

The minimum wage variable, *MINA*, is treated essentially as a dummy variable since it is zero in all states in 1960 and $1.30 in all states in 1970. Thus any trending shifters of supply or demand left out of the regressions will bias the minimum wage variable. The interaction term between the minimum wage and schooling does give us cross-sectional contrasts of minimum wage effects. Thus, the regression results should give more reliable estimates of the effect of schooling on minimum wage effects than of the overall effect of the minimum wage on the labor market.

The variable *LAND* representing the number of acres (in millions) of land in farms (U.S. Department of Commerce 1972) is included in the demand function to account for this input and in both supply and demand functions to adjust for effects of state size. A quantity rather than a price variable is used on the assumption that a state's supply curve of farmland is relatively inelastic. Land is, of course, a far from homogenous input, and some types of land, such as prime cropland, undoubtedly increase the demand for labor more than others. And gov-

ernment programs in this period influenced shifts of some land to such less labor-intensive uses as pasture. On the other hand, these same programs probably induced greater labor-intensive use of land which remained in the major cash crops. Not knowing the net effect, it was judged sufficient for purposes of this paper to use the straightforward quantity variable in acres to represent a state's size. Regarding state size effects, one could, alternatively, put all data on a per-farm basis. However, this would be undesirable since size of farms is an endogenous variable which differs greatly across states and is itself in part a measure of labor quantity, with one operator per farm.

Perhaps the most important variable omitted is a measure of product demand conditions. Holding an index of farm product prices constant would be inappropriate since the analysis is at the industry, not the firm level. But it is not possible to distinguish the exogenous shifters of demand (population, consumer income, etc.) for each state's farm products when farm products are sold in a national market.[1] Since real U.S. civilian expenditures on farm food increased 21% and the real value of food and live animal exports increased by 24% (U.S. Bureau of Census 1976) between 1960 and 1970, demand must have increased. Consequently, product demand shifts would have increased farm employment, *ceteris paribus*, and our specification could for this reason understate the decline in employment due to the minimum wage.

Table 1. Reduced Form Regression Coefficients Explaining Hired Farm Worker Employment and Wages

Exogenous Variables	Endogenous Variables: Employment (25.35 thousand)[a]	Wage ($.96 per hour)
MINA	−69.8	.804
($.966 per hour)[a]	(21.8)[b]	(.267)[b]
S	−3.05	.057
(8.55 years)	(1.43)	(.018)
SMINA	6.58	−.084
(8.26)	(2.53)	(.031)
AGE	−1.56	.084
(34.0 years)	(2.94)	(.036)
$(AGE)^2$	0.038	−.001
(1190.)	(0.047)	(.0006)
WN	−7.88	.311
($2.29 per hour)	(4.12)	(.051)
REX ($t-1$)	2.77	−.005
($8.47 million)	(0.367)	(.004)
LAND	0.148	−.001
(23.8 million acres)	(0.053)	(.0006)
XK	0.901	.007
($5.72 billion)	(0.410)	(.005)
Intercept	51.2	−1.24

Note: Alaska, Hawaii, and Rhode Island are excluded, so the number of observations is 94.
[a] The 1970 means of the variables are provided in parentheses. All monetary variables are expressed in real (1957–59 = 100) dollars.
[b] Numbers in parentheses below estimated coefficients are standard errors of coefficients.

Results of Estimation

Regression coefficients for the two reduced-form equations are obtained using pooled state data for 1960 and 1970. In ordinary least squares (OLS) regressions with pooled cross-section and time series data, there may be a problem with nonindependence of errors. In particular, there may be a state or region specific error component. For example, knowledge of the difference between the predicted and actual wage for California in 1960 may provide information about the error expected for California in 1970. However, a search for region-specific errors found no significant error components. Therefore, OLS regressions are used.

The estimated coefficients for the reduced form equations are provided in table 1. Their signs are as expected. The minimum wage increases the average farm wage and decreases employment of hired workers. As found by Gisser, increased schooling decreases employment and increases wages. Finally, the hypothesis concerning the schooling-minimum wage interaction coefficient is verified. This interaction coefficient suggests that the increase in wage and decrease in employment due to the legislated minimum are reduced as the level of schooling of hired farm labor increases.

The effect of schooling-minimum wage interaction is shown in table 2, which presents the estimated effects of the minimum wage at different levels of schooling. At seven years of schooling, which is about the mean value for the South in 1970, the agricultural minimum wage has a large impact. But this impact diminishes rapidly as schooling increases. For ten years of schooling, which is the 1970 mean level for farm laborers in a few northern states, the minimum wage has practically no effect.

While the main purpose of the regressions is to estimate the differential effect of the minimum wage associated with schooling differences, the regressions also imply an aggregate effect. This estimate, however, could be influenced easily by misspecification of the model for 1960 as compared to 1970. Evaluating the equations of table 1 at 1970 mean values with *MINA* and *SMINA* set equal to zero indicates that minimum wage legislation increased the hired farm wage rate about 5%, and reduced the employment of farm workers about 42% from what they would otherwise have been in 1970. These

[1] To go one step further, it might be argued that there is only one U.S. hired farm-labor market, in which case using states as observations for regression analysis is inappropriate. This hypothesis implies that in a state cross-sectional reduced-form regression on workers' wages, the factor demand shifters would have coefficients not significantly different from zero, since each state's farm labor supply curve would be perfectly elastic at the going wage. But in this paper and the others on the farm labor market cited above, demand shifters do have significant effects on state farm wage rates.

Table 2. Estimated Percentage Changes in Hired Farm Employment and Wages Due to Minimum Wage Legislation

Mean Years of Schooling	Percentage Change in Employment	Percentage Change in Average Wage
7.0	−63	14
8.0	−50	8
9.0	−34	2
10.0	−14	−2

Note: All other variables in the reduced-form equations are held constant at the 1970 mean levels.

figures do not imply that the demand for workers would be 42% higher if wages were 5% lower. The excess supply at the minimum wage includes the fact that, given nonfarm wage levels, more workers want agricultural employment when farm wages are raised 5%. The 42/5 figure is an estimate of the sum of (absolute values of) the long-run (cross-sectional) elasticities of supply of and demand for farm labor.[2] The long-run supply function of farm labor, given nonfarm wages, is probably quite elastic. Estimation of the structural equations would be required to decompose the minimum wage effects into movements along the demand and supply functions.

Comparing results from other studies, Lianos estimated the employment reduction due to the minimum wage in three southern regions at from 24% to 51%. Others have found much smaller effects at the national level. Schuh (1968) estimated that a minimum wage which increased the wage rate 10% would reduce employment by 4.9% in the long run. Gardner estimated that the minimum wage increased the average wage 13% and decreased employment 18% by 1970, while Gallasch found that a minimum wage which increased the average wage 3% would reduce employment by 15%.

Two alternative formulations of the model were estimated. First, following Mincer, the reduced form equations were estimated with average job experience, measured as age minus years of schooling minus five, replacing the age variable. This substitution had virtually no effect on any of the estimated coefficients, levels of significance, or coefficients of determination. The coefficient of the experience variable was positive in the wage equation and negative in the employment equation, the same signs as the age coefficients.

[2] It should be noted also that there is a wide confidence interval around the employment effect. The 95% confidence interval is −3% to +13% for the increase in the wage rate and 16% to 67% for the reduction in employment. The standard errors for these confidence intervals are obtained using Var ($\beta_1 + S\beta_2$) where β_1 is the regression coefficient of *MINA and* β_2 is the regression coefficient of *SMINA*. Moreover, while the 5% figure is quite robust under alternative specifications of the wage equation, the point estimate of employment change varied substantially under alternative specifications of the employment equations (e.g., leaving out variables or lagging *REX*).

Second, the notion that experience is theoretically preferable to age as an independent variable rests on experience being a better proxy for the accumulation of human capital via on-the-job training. This suggests that there may be an experience-minimum wage interaction in addition to the schooling-minimum wage interaction. Accordingly, the reduced-form equations containing the experience variables were reestimated with the addition of a multiplicative experience-minimum wage variable. The coefficients had the expected signs—negative in the wage equation and positive in the employment equation, because mean experience occurs in the rising part of the life-cycle of wage rates—but were not significant at the 90% confidence level. Estimated effects of the minimum wage were increased slightly in absolute value.

Conclusion and Implications

Our efforts were directed toward analysis of the impact upon farm labor of minimum wages, schooling, and the interaction between them. The reduced form equations suggest that schooling and minimum wages have similar impacts on wages and employment. A higher level of schooling or imposition of and/or increases in a minimum wage will increase the average wage and decrease employment. Obviously the social impact of this disemployment differs in each case.

Our results suggest two approaches as alternatives to the minimum wage to help raise farm wages without at the same time restricting employment opportunities. The first is shown in the elasticities of average wage and employment with respect to the expected nonfarm wage. These elasticities, using the coefficients from table 1 and 1970 means, are .6 and −1., respectively. Thus, a 10% increase in nonfarm wage increases the average hired farm wage by 6% and reduces hired farm worker employment by approximately 10%. While general economic growth in the nonfarm sector, like the minimum wage, increases the farm wage rate and reduces farm employment, migrants who leave the farm sector in response to the pull of this invisible hand are more likely to find satisfactory employment than are the low-schooled workers displaced from agriculture by the invisible foot of the minimum wage. These latter workers probably will go predominantly into noncovered jobs, such as self-employment in farming (which includes sharecropping) or other rural self-employment, increasing the labor force and reducing labor returns in these activities.

The second policy alternative is improvement in the schooling or experience attainments of hired farm workers. As previously indicated by Gisser and as reinforced by our own results, higher levels of schooling for farm workers facilitate out-migration of farm workers resulting in increased hired farm worker wages. Using the estimated equations

and 1970 means of the variables, our results suggest that without the minimum wage (i.e., *MINA* and consequently the interaction term are zero), a 10% increase in the average level of schooling brings about an 8% reduction in employment and a 3% increase in average wage rate. The ability of schooling to raise farm wages is diminished by the presence of the minimum wage.

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Contemporary Issues in Natural Resource Economics
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On the Foundations of Intertemporal Choice

John Ferejohn and Talbot Page

How are we to make decisions concerning nuclear power, ozone depletion, fossil fuel combustion and the greenhouse effect, chemical carcinogens and mutagens, and the like? The most commonly advocated and most commonly used criterion for these and other intertemporal decisions is the maximization of discounted net benefits. However, this criterion is often criticized as being unfair to future generations, although it is not always clear what is meant by unfair.

In this paper, we consider intertemporal choice from an axiomatic perspective. By doing so, it is possible to discuss intertemporal choice rules in terms of the properties that characterize them. The long term hope of this approach is to interpret and select intertemporal choice rules that satisfy some axioms describing fairness of efficiency. Concepts of fairness often reduce symmetry requirements on the choice procedures and the axiomatic level is a useful one for considering alternative symmetry conditons. In the long run this approach may yield a more explicit idea of what is meant and what can be meant by the term intertemporal equity. Our purposes in this paper are more modest; they are, first, to establish the structural framework and reinterpret some previous results within this intertemporal choice context and, then, to show that, in a surprisingly strong fashion, the discounting rule fails a test of fairness.

Two Approaches to Intertemporal Choice

We can identify the most commonly used approach to intertemporal choice in the literature on economic growth and resource economics as a planning approach. In this approach there is a criterion that ranks alternative social states, where a social state is an entire intertemporal program. More formally, we have X: the set of alternative programs (states of the world), and R: a rule which pairwise ranks states for $\mathbf{x},\mathbf{y} \in X$; $\mathbf{x}R\mathbf{y}$ means that $\mathbf{x}$ is at least as good as $\mathbf{y}$.

In most of the growth and natural resources literature, the rule R is taken to be the discounting rule defined by

$$(1) \quad \mathbf{x}R\mathbf{y} \Leftrightarrow \sum_{i=1}^{\infty} \alpha^{i-1}U(\mathbf{x}_i) \geq \sum_{i=1}^{\infty} \alpha^{i-1}U(\mathbf{y}_i),$$

where $\mathbf{x}_i$ is a description of the economy at time i, under state $\mathbf{x}$ (usually $\mathbf{x}_i$ is the consumption at time i), and similarly, $\mathbf{y}_i$ is a description of the economy at time i, under state $\mathbf{y}$; α is the rate of discount and is between 0 and 1; and U is an "instantaneous" utility function, usually strictly concave.

Note that we are already beginning an interpretation which is more general than is the usual spirit of growth theory and resource economics. The utility condition on the right hand side of (1) has cardinal aspects, while the ranking rule on the left hand side is an ordinal concept. Moreover, on the left we have a general state of the world $\mathbf{x}$, describing present and future conditions, while on the right we have characterized by a sequence of snapshots, $\mathbf{x}_i$, one for each moment of time or each generation.

By planning approach, we mean that the focus of attention is not principally on the derivation of the choice rule R but upon its satisfaction—finding the best $\mathbf{x} \in X$ under R. For example, in Arrow and Kurz' *Public Investment, the Rate of Return, and Optimal Fiscal Policy,* four pages are spent upon the derivation of the criterion function and 200 on

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its satisfaction. R is the planner's criterion, but this is not to suggest that the criterion might not have broad appeal, far beyond the planner's own preferences.

Alternatively, we could start with a preference structure for each generation and focus our attention on the problem of aggregating these individual preferences into a single intertemporal social ordering. To focus on the problem of intertemporal aggregation we assume that each generation acts like a single unit with R_i as the preference ranking of generation i ($\mathbf{x}R_i\mathbf{y}$ means that generation i values social state $\mathbf{x}$ to be at least as good as $\mathbf{y}$), and our problem is to find an aggregation procedure F that combines the individual preference orderings into a single, intertemporal ordering R: $F{:}\mathrm{R}^{\infty} \rightarrow \mathrm{R}$, where R is the set of complete, transitive, and reflexive binary relations on X. This, of course, is but a slight reinterpretation of the approach taken in Arrow's *Social Choice and Individual Values*. In this paper we follow the latter approach and focus principally on the aggregation problem.

There are some obvious differences between social choice in an intertemporal setting and in the more usual intratemporal setting. Time runs one way and is not bounded. The present must choose in the absence of the future's representatives, and the choice is almost always not once and for all time but sequential. Thus, in the intertemporal context, new problems arise and old ones may disappear. Even though decisions can only be made by those in the present generation, we assume that decisions should take into account the preferences of the affected individuals, future as well as present. Obviously, we in the present, who must make decisions, do not know the detailed pattern of the future's preference rankings; nonetheless, some things can be said about the properties of choice rules in the absence of this kind of knowledge.

Dominance Rule

Chakravarty and others have argued that the time horizon for problems of intertemporal choice should be considered infinite. For one thing, there is no satisfactory way to determine the last generation or last period, and once a terminal period is chosen there is still the problem of evaluating the terminal stock. For each choice of a terminal period for which evaluation is to stop, we must look ahead at least one more period. As Chakravarty puts it, "the argument for using an infinite horizon is logically very compelling, stemming as it does from the very axioms of Peano regarding the set of integers" (p. 20). For this reason we take the set of generations over which F is to aggregate to be infinite.

The possibility of an infinite number of individuals or generations can have important consequences for the theory of social choice. The following result, due to Hansson, is convenient for an interpretation in the intertemporal context.

Let N be the set of individuals in the intratemporal case, where N is finite with number n; and let N be the set of generations in the intertemporal case, where N is infinite. Recall Arrow's four axioms:

TRANSITIVITY *(T)*: *The range of F is restricted to the set of R, each member of which is complete, reflexive, and transitive (i.e., weak order).*

BINARY PARETO *(P)*: *If $\mathbf{x}P_i\mathbf{y}$ for all $i \in N$, then $\mathbf{x}P\mathbf{y}$.*[1]

INDEPENDENCE OF IRRELEVANT ALTERNATIVES (I): *If there are two profiles of individual rankings $R_iR'_i$ such that $\mathbf{x}R_i\mathbf{y} \Leftrightarrow \mathbf{x}R'_i\mathbf{y}$ for all i, then $\mathbf{x}R\mathbf{y} \Leftrightarrow \mathbf{x}R'\mathbf{y}$.*

NONDICTATORSHIP: *There is no generation i such that $\mathbf{x}P_i\mathbf{y} \Rightarrow \mathbf{x}P\mathbf{y}$ for all $\mathbf{x}$ and $\mathbf{y}$ and all possible profiles of individual rankings.*

We define a set $c \subseteq N$ as decisive if $\mathbf{x}P_i\mathbf{y}$ for all $i \in c \Rightarrow \mathbf{x}P\mathbf{y}$. Let W denote the collection of decisive sets. Indirectly, the decisive sets are defined in terms of the aggregation rule, F. Hansson has shown that if the aggregation rule F satisfies P, then W must exhibit the following properties (W is an ultrafilter):

1. $N \in W, \phi \notin W$
2. $c \in W \quad c \subseteq d \Rightarrow d \in W$
3. $c, d \in W \Rightarrow c \cap d \in W$
4. $c \notin W \Rightarrow N - c \in W$

Arrow's Theorem may then be stated as follows: *If $n < \infty$, then every decisive set is a superset of a single individual (there is an $i \in N$ such that $c \in W \Leftrightarrow i \in c$).* That is, there is an individual, i, who, if he has $\mathbf{x}P_i\mathbf{y}$, society has $\mathbf{x}P\mathbf{y}$-a dictator. If, however, N is infinite, then there are families of decisive sets satisfying properties (1) through (4) for which there is no dictator.

Hansson has shown, in fact, that there are infinitely many aggregation procedures, F, that are nondictatorial. Moreover, although

[1] Strong preference P is defined by $\mathbf{x}P\mathbf{y} \Leftrightarrow \sim \mathbf{y}R\mathbf{x}$.

there is no simple characterization of the complete structure of this class of nondictatorial aggregation rules, they all have the property that if $c \subseteq N$ has a finite complement (c is cofinite) then $c \in W$. This means that the nondictatorial F are voting rules with the following property: if an infinite number of generations prefer $\mathbf{x}$ to $\mathbf{y}$, and only a finite number prefer $\mathbf{y}$ to $\mathbf{x}$, then the social choice is $\mathbf{x}$ to $\mathbf{y}$. This property of the nondictatorial aggregation procedures is only a partial description, because the cofiniteness property does not tell us how $\mathbf{x}$ and $\mathbf{y}$ should be socially ranked if an infinite number of generations prefer $\mathbf{x}$ to $\mathbf{y}$ and an infinite number prefer $\mathbf{y}$ to $\mathbf{x}$.

At least for the decisions involving an infinite set against a finite set, there is no time bias. Swapping preference orderings of a generation far from the present with the orderings of a generation near the present will not change the outcome of the social decision. Moreover, it can be shown that the intersection of the collection of decisive sets is empty, and that the size of any decisive set is infinite. This contrasts with the dictatorship case, where the intersection of decisive sets has exactly one element, the dictator, and of course the size of the smallest decisive set is one, not infinity.

Time induces a natural ordering of generations, and because time is one way, with a first or present generation but no last generation, the intertemporal interpretation of the cofiniteness rule introduces an asymmetry with respect to time (not necessarily interpretable as bias, as we have just seen). If c is a finite set, and hence $N - c$ is a decisive set and $\mathbf{x}$ is preferred to $\mathbf{y}$ in $N - c$, then there will be a time t for which all the generations beyond t will unanimously prefer $\mathbf{x}$ to $\mathbf{y}$. This will be recognized as an ordinal version of the "overtaking criterion" which says that if there is a t such that $\mathbf{x}P_i\mathbf{y}$ for all $i > t$, then society should choose $\mathbf{x}$ over $\mathbf{y}$. The cardinal version has been justified in terms of its mathematical usefulness in making integrals converge (see Gale, Ramsey, and Weizsacker), and it is interesting to see the ordinal version turn up on a completely different basis, as a result of P,I and $n = \infty$.

The axiomatic basis for the overtaking rule permits us to judge the ethical appeal of the rule by the appeal of its axioms, as well as the further implications of the axioms; and to compare this rule with the discounting rule, on the basis of axioms that characterize it. It should be stressed that finding an axiomatic basis of the overtaking principle, which is nondictatorial, does not "solve" the aggregation problem. First of all there are infinitely many different aggregation rules that incorporate the overtaking rule and satisfy Arrow's axioms; second, there are definite limitations to the ethical appeal of the overtaking rule. It is disturbing that the next 100 generations do not count in the social choice, and not particularly reassuring that any other 100 generations are no more important. The pie-in-the-sky quality of the overtaking rule no doubt disqualifies it as a practicable decision rule by itself. One point is that this unattractive feature is embodied in P, I, and the nonfinite horizon. A major purpose of the analysis is to discover how various axioms relate and embody various ethical values. We know, for instance, that if we give up the nonfinite horizon, we must give up the nondictatorship as well, if we wish to keep P and I. A second point is that even though we may not subscribe to the overtaking rule as the only criterion of choice, there may be ethically attractive aspects of the rule which we might want to incorporate into other rules.

Arrow's Theorem has just been stated and interpreted in its general form, in which both X and the preference orderings have little structure. X is a set of states or plans and the preference orderings are merely required to be complete, reflexive, and transitive. In discussions of intertemporal decisionmaking and, in particular, in discussions of discounting rules, there is usually considerably more structure in both the state space and the preferences. To start with, as we have assumed in (1), the state space consists of snapshots in time, $\mathbf{x} = (\mathbf{x}_1,\mathbf{x}_2, \ldots)$. With states disaggregated into sequences, it is convenient to introduce the notation of the continuation of a sequence ${}_t\mathbf{x} = (\mathbf{x}_t, \mathbf{x}_{t+1}, \ldots)$. Frequently we would like to interpret $\mathbf{x}_t$ as a vector of consumption at time t and $\mathbf{x}$ as a program of consumption bundles. Furthermore, we may require that preferences be monotone ($\mathbf{x} \geq \mathbf{y} \Rightarrow \mathbf{x}R_i\mathbf{y}$ for all i) convex, and continuous. These characterizations seem somewhat more natural for the evaluation of intertemporal decisionmaking. Moreover, they provide a context more compatible for an axiomatic discussion of the discounting rule.

Kalai, Muller, and Satterthwaite have proved a version of Arrow's Theorem, with these restrictions, and we have extended it. Let $\mathbf{X}$ be a normed vector space and let Q

denote the set of convex, continuous, monotone, weak orderings on $\mathbf{X}$.

THEOREM: *If F maps Q^n into R in such a way that the independence and Pareto conditions are satisfied, then there is a set W (the collection of decisive sets) satisfying properties* (1) *through* (4) *above.* Kalai and his colleagues have proved the theorem in the finite case ($n < \infty$), in which case there is dictatorship, but their argument goes through as well in the infinite case, in which case there are nondictatorial social decision rules, all incorporating the overtaking rule.

A model with the above restrictions on X and preferences can arise quite naturally. Suppose, for example, that a society is evaluating a path of consumption, where feasible consumption is constrained by production conditions: that is,

$$X = \{(\mathbf{c}_1, \mathbf{c}_2, \dots) \mid \mathbf{y}_t = f(\mathbf{s}_{t-1}) = \mathbf{s}_t + \mathbf{c}_t, \text{ for all } t \geq 1\}.$$

We might wish to require that each generation have continuous, convex, and monotone preferences over the $(c_1, c_2, \dots)$.

The Discounting Rule

In a stimulating series of papers, Koopmans has provided an axiomatic basis for the discounting rule. Since both sets of axioms seem to have consequences for intertemporal choice, it seems useful to investigate how Koopmans' axioms relate to those of Arrow. In particular, since Koopmans' axiom of stationarity appears to be critical in developing the discounting rule, we will focus on how this axiom relates to Arrow's I and P. But first we will briefly outline Koopmans' axiom system. The set of alternatives is denoted by $X^\infty = X \otimes X \otimes X \otimes, \dots, \dots$

(*a*) *R is a complete, reflextive, transitive, binary relation on X^∞ that is continuous under a sup norm on X^∞.* Koopmans uses this axiom to assert that there is a function $V: X \rightarrow (-\infty, \infty)$ such that

$$\mathbf{x}R\mathbf{y} \Leftrightarrow V(\mathbf{x}) \geq V(\mathbf{y}).$$

(*b*) STRONG INDEPENDENCE. *Given a preference ordering R on X^∞ define the following binary relations:*

$$\mathbf{x}_t R_t(\mathbf{z}) \mathbf{y}_t \Leftrightarrow (\mathbf{z}_1, \dots, \mathbf{z}_{t-1}, \mathbf{x}_t, \mathbf{z}_{t+1}, \dots) R(\mathbf{z}_1, \mathbf{z}_2, \dots, \mathbf{z}_{t-1}, \mathbf{y}_t, \mathbf{z}_{t+1}, \dots)$$

$$(\mathbf{x}_t, \mathbf{x}_{t+1})\, Q_t(\mathbf{z})\, (\mathbf{y}_t, \mathbf{y}_{t+1}) \Leftrightarrow (\mathbf{z}_1, \mathbf{z}_2, \dots, \mathbf{z}_{t-1}, \mathbf{x}_t, \mathbf{x}_{t+1}, \mathbf{z}_{t+2}, \dots) R_t(\mathbf{z}_1, \dots, \mathbf{y}_t, \mathbf{y}_{t+1}, \mathbf{z}_{t+2}, \dots).$$

We say that R satisfies strong independence if the relations $R_t(\mathbf{z})$ and $Q_t(\mathbf{z})$ do not depend on $\mathbf{z}$. For our interpretation, we can identify $R_t(\mathbf{z})$ with generation t's preference ordering, although Koopmans does not make this interpretation, nor is a definition of individual generational preference orderings necessary in his axiom system. Under our identification of $R_t(\mathbf{z})$ with generation t's preference ordering, there is common sense appeal to the axiom—if two programs are exactly the same for all time except for one generation, that generation's preferences should determine the social choice.

This axiom, along with the first, implies additive separability of the utility function, along with an important measure of cardinality. For example, it allows us to write the utility function $V(\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_3)$ as $V^1(\mathbf{x}_1) + V^2(\mathbf{x}_2) + V^3(\mathbf{x}_3)$ in the three period case.

(*c*) EXTREME PROGRAMS: *There exist $\bar{\mathbf{x}}$, $\mathbf{x}$ such that $\bar{\mathbf{x}}R\mathbf{x}$ for all $\mathbf{x} \in X^\infty$ and $\mathbf{x}R\mathbf{x}$ for all $\mathbf{x} \in X^\infty$.*

(*d*) SENSITIVITY: *There exist $\mathbf{x}_1$, $\mathbf{x}'_1$ and ${}_2\mathbf{x}$ such that $(\mathbf{x}_1, {}_2\mathbf{x})P(\mathbf{x}'_1, {}_2\mathbf{x})$.*

(*e*) STATIONARITY: *R satisfies stationarity if* $(\mathbf{x}_1, {}_2\mathbf{x})R(\mathbf{x}_1, {}_2\mathbf{y}) \Leftrightarrow ({}_2\mathbf{x})R({}_2\mathbf{y})$.

The intuition of the stationarity axiom is that if two programs agree in their first component and one is preferred to the other, then if both were shifted forward one period, the same social preference ordering between the two modified programs would hold.

The last three axioms imply that there is a function $U: X \rightarrow (-\infty, \infty)$ and a number α between 0 and 1 such that V can be written as follows:

$$V(\mathbf{x}) = \sum_{t=1}^{\infty} \alpha^{t-1} U(\mathbf{x}_t),$$

which is the previously given discounting rule.

It appears that the stationarity axiom plays an especially important role in Koopmans' characterization. Obviously, the Koopmans axioms taken together are at odds with Arrow's since the discounting criterion is not consistent with Arrow's postulates. We shall now try to pinpoint the source of this inconsistency.

We show now that an Arrowian intertemporal aggregation procedure F which satisfies stationarity must be dictatorial even if there are infinitely many generations. Furthermore,

the first generation must be the dictator. (For an introductory discussion, see "Intertemporal Equity" in Page.)

DEFINITION: F: $\mathrm{R}^\infty \to \mathrm{R} \subseteq \mathrm{R}$ *is stationary if and only if* R *is the subset of weak orders satisfying stationarity.*

THEOREM: *If* F: $\mathrm{R}^\infty \to \mathrm{R}$ *satisfies P and I, then the family of decisive sets under F may be written:* $W = \{c \subseteq N \mid \epsilon\ c\}$.

Proof: Let $R(X)$ be a particular ordering on a single factor of X^∞ satisfying $\mathbf{x}_1 P(X)\mathbf{x}_2$ for $\mathbf{x}_1, \mathbf{x}_2 \in X$. Then we construct a preference ordering $\pi = (R_1, R_2, \ldots)$ as follows:

$$\forall\, i \in N\ \forall \mathbf{u},\mathbf{v} \in X^\infty,\ \mathbf{u}R_i\mathbf{v} \Leftrightarrow \mathbf{u}_i R(X)\mathbf{v}_i.$$

Thus, in π, individual i has $\mathbf{u}$ strictly over $\mathbf{v}$ if, and only if, he strictly prefers the ith component of $\mathbf{u}$ (namely $\mathbf{u}_i$) to the ith component of $\mathbf{v}$.

Now consider the following programs:

$$\begin{aligned}\mathbf{x} &= (\mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \ldots),\\ \mathbf{y} &= (\mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \ldots),\\ \mathbf{z} &= (\mathbf{x}_1, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \ldots),\end{aligned}$$

and

$$\mathbf{w} = (\mathbf{x}_2, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \mathbf{x}_2, \mathbf{x}_1, \ldots).$$

Note that on the pair $\{\mathbf{x},\mathbf{y}\}\ \forall\, i \in c = \{1, 3, 5, 7, \ldots\}$, $\mathbf{x}P_i\mathbf{y}$ and $\forall\, i \in N - c$, $\mathbf{y}P_i\mathbf{x}$. In view of property (4) (in second section—"Two Approaches to Intertemporal Choice"), either c or $N - c \in W$, so that either $\mathbf{x}P\mathbf{y}$ or $\mathbf{y}P\mathbf{x}$. If $\mathbf{y}P\mathbf{x}$, then $\{2, 4, 6, 8, \ldots\} \in W$ and stationarity implies that $\mathbf{x}P\mathbf{z}$ and $\mathbf{w}P\mathbf{y}$. Thus by transitivity $\mathbf{w}P\mathbf{z}$. But for all $i \in \{1, 2, 4, 6, 8, \ldots\}$, $\mathbf{z}P_i\mathbf{w}$ so we must have $\mathbf{z}P\mathbf{w}$, a contradiction. Thus, necessarily $\mathbf{x}P\mathbf{y}$ and so $\{1, 3, 5, \ldots\} \in W$.

Then consider the pair $\{\mathbf{z},\mathbf{x}\}$. Note that stationarity requires that $\mathbf{z}P\mathbf{x}$ (since $\mathbf{x}P\mathbf{y}$). By the same argument we have $\mathbf{y}P\mathbf{w}$. Thus the transitivity of R implies that $\mathbf{z}P\mathbf{w}$. But note that the set of individuals with $\mathbf{z}P_i\mathbf{w}$ is just $d = \{1, 2, 4, 6, 8, 10, \ldots\}$, and that $N - d$ cannot, therefore, be decisive. Thus, d is decisive (by property 4) and so, by property 3, $c \cap d = \{1\}$ is a decisive set. Application of property 2 completes the proof.

In view of the fact that in the intertemporal case there are infinitely many aggregation procedures F which satisfy I and P, the addition of the stationarity axiom substantially reduces the admissible procedures. We have not yet determined if a stronger result of the following kind is available. Namely that P, I, and stationarity may be inconsistent by themselves. We have simply shown that if an interposed temporal aggregation procedure exists which satisfies P, I, and stationarity, then generation one must be a dictator.

Sequential Decisionmaking and Consistent Planning

So far the aggregation procedure F and the intertemporal social choice rule R have been developed as though there were to be just one choice for all time. However, we can imagine that the R_i for $i > 1$ are the present generation's estimates as to the future's preferences. The aggregation procedure F is the present's aggregation, which tries to take into account, in some equitable way, its estimates of future preferences. When time passes, there will be another social choice aggregation problem. If the axioms have simply been passed on from one generation to another (they are invariant under time translation), then the next generation's aggregation rule F (or class of rules F) will be the same as the previous generation's. However, the rules' implied rankings of social states may be different because the first generation's preferences are dropped from consideration and the rest are shifted forward with generation two becoming generation one, and so on.

We can then ask whether or not the rankings of the following generations under the same aggregation rule F will be consistent with past rankings. It is well known that under the discounting rule the rankings of social states will be consistent. The overtaking rule is also consistent. If an infinite number of generations prefer $\mathbf{x}$ to $\mathbf{y}$ and only a finite number prefer $\mathbf{y}$ to $\mathbf{x}$, then $\mathbf{x}P\mathbf{y}$, and this social ordering is maintained when the first generation is dropped and the others shifted forward by one.

Consistency, however, is not a criterion of intertemporal fairness. Consistency means that each generation, given its endowment, which it cannot change, cannot do better by deviating from the preceding generation's plan. Consistency does not mean that the sequence of endowments passed from one generation to another are equitable.

Intertemporal Equity

It seems to us that the results obtained in this paper have important implications for the

issue of intertemporal equity. If the way in which society forms welfare judgments is based on the preferences of the individuals in a "natural" way, then the stationarity postulate requires that generation one is a dictator. Since stationarity is a consequence of the discounting rule (1), and since the necessary presence of a dictator under stationarity, P and I seems unacceptable as principle of intertemporal equity, we conclude that discounting requires fundamental rethinking as a choice rule. Our result suggests that the search for a "fair" rate of discount is a vain one. Instead of searching for the "right" number, "the" social rate of discount, we must look to broader principles of social choice to incorporate ideas of intertemporal equity. Once found, these principles might be used as side conditions in a discounting procedure to rule out gross inequities that can arise with discounting, even with a "low" discount rate.

Some authors have argued that the well-being of future generations ought to be reflected in welfare judgments only to the degree that the present generation feels altruistic towards its descendants. Marglin, for example, says that, "I consider it axiomatic that a democratic government reflects only the preferences of the individuals who are presently members of the body politic" (p. 97). Perhaps such a view would receive widespread assent. Certainly we are not arguing that the allocational institutions be constrained to take someone's estimate of future preferences into account regardless of the feelings of the currently living (and voting) generation. On the contrary, we are suggesting that the present generation might wish to take into account future preferences, not through a direct measure of selfish altruism but by incorporating ideas of symmetry or equity into the aggregation procedure itself.

The examples of intertemporal decisions offered at the beginning of the paper were chosen because they are major decisions, with potentially large impacts on the distribution of welfare for many generations. They involve substantial elements of irreversibility, so that we need to build into them the right amount of equity the first time—to some extent they are one-shot decisions. Moreover, they share the characteristic that affirmative decisions happen to be associated with present benefits and future risks over long periods of time. What happens if the discounted net expected benefit of an affirmative decision is positive, yet only the present generation prefers the affirmative decision, while the next ten or more generations prefer the negative decision?[2] Due to the nature of the risks, competition is unlikely to be possible, and potential Pareto improvements become infeasible if not taken, due to the passage of time. Under a discounting rule, we do not look at the intertemporal distribution of costs and benefits, even though this distribution can be highly skewed.

But a ten-to-one majority is hard to ignore, even in the finite case where we know that majority rule is incompatible with T. Moreover, this distribution of preferences begins to take on the character of an overtaking sequence with an indefinite number of generations. People will differ as to how values concerning intertemporal equity should be built into axioms and the properties of aggregation rules, but even at this rudimentary stage, it appears clear that there is more to intertemporal decisionmaking, than estimating future costs and benefits, choosing a discount rate, and forming a summation. Especially when we are dealing with potentially large-scale irreversibilities with present benefits and future long-term risks.

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Adaptive Economics and Natural Resources Policy

Richard H. Day

The purpose of these remarks is to consider a variously developing, yet coherent approach to economics differing sharply from, but closely related and complementary to optimality and general equilibrium theory, and which, I believe, has a special relevance for natural resources policy. The discussion is introduced by a reflection on the neo-laissez-faireism put forth by some of our most able colleagues as a result of their application of orthodox economics to contemporary resource problems. This is followed by a brief summary of some features of the contrasting theoretical approach I am here to advocate, and which I have referred to elsewhere as adaptive economics (Day 1975). Succeeding remarks point out a few properties possessed by models of this genre, properties that suggest a new perspective on economic policy in general and on natural resources policy in particular. This perspective is the subject of the concluding section.

On Laissez-Faire

At a recent conference on resource scarcity and economic growth,[1] Joe Stiglitz asserted that there is little evidence to suggest the existence of a resource problem, and even if there were, we should probably do nothing about it.[2] This statement would probably astonish laymen, perhaps even be thought bizarre by certain liberal politicians. To well trained economists, however, it is neither surprising nor malevolent. Through the study of optimization and equilibrium, economists gain an understanding of the efficiency of perfect competition. Through a knowledge of economic history, we derive a keen respect for the accomplishments of decentralized enterprise and market processes in overcoming scarcities as they emerge. Through experience with policy formulation and implementation, we acquire a healthy skepticism of the ability of government to improve economic performance as it evolves.

Thus, it is natural for economists to regard contemporary resource shortages as transitory phenomena that will be (or should be) eliminated by price-directed substitutions and by induced technological change. Besides, such empirical evidence of resource scarcity as exists is hotly contested, as was brought out, among other places, at the aforementioned conference on scarcity and economic growth.

Why, then, are we, members of the same intellectual fraternity, gathered here to discuss contemporary issues in resource economics? May I suggest that we are here because we do not believe our own orthodoxy? In my opinion, few economists pursue the subject for its own sake; rather, they pursue it in the belief that contemporary economic problems need solution through proper analysis and effective policy. This behavior reveals a further belief either (*a*) in the imperfection of the existing system: its social or technical inefficiency, its imbalances of supply and demand, its monetary instabilities, its persistent misallocation of resources eventually to bankrupt enterprises, its working to make individuals, groups, even entire cultures, worse off; or (*b*) that other competitive equilibria than those that are supposed to exist are better and should be brought about by a redistribution of resources through nonmarket policies.

Thus, while it may be natural for us to hold a prejudice in favor of market mechanisms, it is also common for us to find room in them for improvement, modification, or augmentation by alternative allocation procedures.

Having motivated a concern for policy I want now to look at a particular approach to

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[1] The conference on "The Economics of Natural Resource Scarcity," held at Resources for the Future, Washington, D.C., 17–18 Oct. 1976.

[2] Paraphrased from memory.

economic theory which, it is to be argued, lends a new perspective to policy.

On Adaptive Economics

The basic problem of adaptive economic theory is to explain how the dynamics of economic evolution are derived from the behavior of individuals and organizations. There are certain factors to be explained by this theory on the basis of plausible axioms of behavior.

The facts to be explained include, first, the emergence of complex trajectories of economic change involving growth, fluctuation, and decay, overlapping waves of specific production and consumption technologies and switches in the underlying structure of activity and resource constraints; second, the seemingly irresistible movements that harm some individuals, groups, and entire cultures, leading in extreme but not infrequent cases to their demise; and third, instabilities and inefficiencies that appear to be robust with respect to policies designed to control them.

The axioms of behavior, on the basis of which these facts are to be explained, formalize the following observations: (*a*) economic activity changes the environment within which further activity is conceived and executed: economic artifacts are more or less durable, including irreversible effects on the environment, such as pollution or resource exhaustion that follow as consequences of production and consumption activity; (*b*) economizing is carried out by agents who are partially informed, have limited memory and computational powers, and who can make only imperfect forecasts of the effects of their choices; (*c*) the current state of knowledge derives from, and can derive from only, the past operation of the system; (*d*) economic activity, including planning, takes time, so that delays intervene between plans, actions, and consequences; (*e*) plans and behavior are imperfectly coordinated, so economic behavior takes place out of equilibrium. Adaptive economics does not begin with structures of rationality and equilibrium (although those concepts are necessarily involved). Rather it begins with an assumption that change evolves from current conditions, and focuses on the economizing of partially informed agents whose transactions are imperfectly coordinated, who use various adaptive procedures—such as servomechanism, behavioral learning rules, optimization with feedback, and the like—and whose numbers, activities, rules of behavior, and organizations evolve. It is primarily the study of how economies adapt in disequilibrium and secondarily whether or not, and if so, how equilibria or states of adaptedness are achieved.

Note that our subject is not opposed to equilibrium theory. Quite the contrary, for concepts of rationality and equilibrium define states of optimal adaptation which provide a benchmark against which disequilibrium performance may be compared. But the convergence of adapting processes to optimal states is not to be taken for granted. In the biological world (of which we are of course a part), evolution proceeds by various trials and errors, producing local and temporary adaptation at best, more or less improving fitness sometimes, and monstrosities, anachronisms, and extinctions much of the time. In economics we encounter similar phenomena. Our interest in adaptation must, therefore, surely not be motivated by a desire to mimic in human affairs the blind profligate and callous mechanism that governs other species, as was advocated by the Social Darwinists, but rather to understand better and to make possible the more effective participation of human intellect in the evolutionary process that governs life, in general, and conditions human affairs, in particular.

It should also be noted that the concepts of economizing, economic equilibrium, adaptation, and evolution have been intertwined throughout much of their development. The biologist Darwin attributed his inspiration to the economist Malthus, while Marshall—most notably among neoclassical scholars—drew extensively on biological analogies in describing the process by which firms adapt to their market environment by means of incremental adjustments and by which low-cost firms drive high-cost competitors out of existence.

Although some economists, such as the great Ragnar Frisch, recognized the explicitly adaptive, evolutionary character of Marshall's economics, the latter have received much less attention than have the associated concepts of equilibrium or adaptedness for which Marshall is indeed primarily remembered.

But adaptive economics is not merely new skin for old wine. It is a body of theory in the process of construction and from which we should expect many new insights as its parts grow and mature.

Adapting in Disequilibrium

From a purely formal point of view it would appear that adaptive behavior takes two distinct forms, one of which is servomechanistic and which I shall call determined homeostasis and the second of which involves bounded rationality and which I shall call optimizing with feedback.

In the first form, determined homeostasis, actions are adjusted on the basis of an observed discrepancy between a desired or target value of one or more critical variables and their experienced values. Extensively developed by Canon, in the context of physiology, and by Brown and Campbell (for example), in engineering, the idea seems first to have been applied to the study of human behavior by Cooper, Simon, March and Simon, Boulding, and Forrester, and is the basis of the Goodwin-Chenery flexible accelerator (Goodwin, Chenery). It may be noted that determined homeostasis can be interpreted as an algorithm for minimizing the distance between target and observed outcomes and reveals a preference for outcomes closer to the target than others. It should also be observed that this form of behavior appears most often to be "wired in," i.e., affected by physical-chemical mechanisms, tradition, or other nonreflective devices.

In the second general form of adaptive behavior, explicit, as opposed to implicit, optimizing occurs. At a given point in real time, the agent perceives a set of feasible actions and selects a best member in this set according to an objective function or preference preordering. The perceived feasible set, or the objective function, or both, are then adjusted in response to experience. Several specific types of this general form can be distinguished, three of which are briefly summarized.

The behavioral learning algorithm. In this system of switches and rules (Day 1975), the rule governing behavior at any time is determined when a performance measure (outcome) belongs to the rule's associated switching set. A change in the performance measure sufficient to bring its value to a different level causes a change in action and a switch in the rule governing behavior. Simple examples can be constructed readily using four elemental principles of learning: (*a*) successful behavior is repeated; (*b*) unsuccessful behavior is avoided; (*c*) unsuccessful behavior is followed by a search for alternative action or modes of behavior; (*d*) search becomes more cautious in response to failure. Well founded in psychological theory and experimentation, models incorporating the first three principles have been the basis of the behavioral theory of the firm developed by Cyert and March. In Day (1967) and in Day and Tinney, it is shown that behavioral learning models augmented by failure response can converge to the traditional equilibrium for individual monopolistic or two agent monopolistic teams with stationary environments, though little is known about their performance in more complex settings. Recently, empirical evidence has been assembled that indicates businesses are actually governed by such rules (Crain and Tollison, undated).

We note that the behavioral learning model can be formulated as an extremely simple local or approximate optimizing of marginal variation in action based on extremely limited use of past results; formally, a simple recursive linear programming model. This brings us, then, to the second type of model based on optimization with feedback.

Recursive programming models. In these models, economic plans and behavior are represented by explicit maximizing models, such as linear, nonlinear, or dynamic programs, but with the assumption that actual outcomes are determined by additional forces unaccounted for in the individual optimizations. For this reason, the optimizations are in fact suboptimizations, as in the simpler behavioral learning case. These additional forces may act on the agent through environmental feedback, through estimates of current and forecasts of future states, and through behavioral rules that make allowances for future decisionmaking, that modify objectives on the basis of past behavior, and that limit change from established behavior as a tactic for avoiding uncertainty. Models of this type take a great variety of specific forms, examples of which may be found in Day and Groves and especially in Day and Cigno.

Adaptive programming or dual control. When applying strategic considerations to the problem of adaptation, the agent must account for all decision functions: observation, storage, processing, planning, and implementation. And, in choosing a course of action, he must consider the advantage to be gained by allocating present resources to learning about the system through conscious experimentation as compared to their allocation for maximizing

current performance, given the current level of knowledge of the system's operation. Formal models that embody these considerations are called adaptive or dual control models and were originated by Fel'dbaum in a generalization of dynamic programming and stochastic programming techniques (Bellman). Extensively studied by control engineers, various examples have been described in several recent surveys; for example, Aoki (1977).

At this point, however, it is important to note the following. The more inclusive is the range of decision-making considerations explicitly incorporated within the adaptive control framework, the more complex, costly, and time consuming the implied algorithm for obtaining "optimal" decisions. Such costs rise more or less exponentially with the level of detail accommodated, so that the model in practice must be an extreme simplification of actual operating conditions. Even so, the method involves substituting a complex and extremely costly computational algorithm for real-time servomechanistic procedures, behavioral learning, or simple, tactical optimizing.

Now, if the decision-maker has something to learn about the structure of the environment, and not merely the value of certain environmental parameters, then one cannot be sure that sophisticated adaptive strategies will perform better than the simple tactics they replace. Whether or not and under what conditions they will perform better depends on the true environment and how stable the adaptive control model is when plans roll and knowledge evolves. Evidently, adaptive control models must belong in practice to the general class of optimization with feedback models representing bounded rationality.

Disequilibrium Mechanisms

All those considerations of adaptation and evolution must lead to an emphasis on disequilibrium phenomena in adapting—as opposed to adapted—systems: the disappointment of expectations, imperfect coordination of separately managed enterprises, the inequation of supply and demand, inefficiencies in the allocation of resources, and declining as well as improving fortunes of some participants in the system. The extent of these phenomena may be greater at one time than at another. At all times they pose threats to survival. The primary concern of the firm, then, must be for its survival, while the institutional development of society must be guided to a considerable degree by the need to maintain viability in the face of disequilibrium.

For the individual, as well as for the organization, caution is an element strongly influencing adaptive behavior, and a part of cautious behavior is the maintenance of stocks of unused resources and the existence of slack to absorb unpredictable divergences between plans and realizations. In addition, organizations evolve whose functions are to mediate disequilibrium transactions and to sustain critical variables within homeostatic bounds. Stores, for example, function as inventories on display mediating the flow of supplied and demanded commodities without the intervention of centralized coordination or of complicated and time-consuming market tatonnement procedures. Banks and other financial intermediaries regulate the flow of purchasing power among uncoordinated savers and investors and mediate the flow of credits and debts that facilitate intertemporal exchanges without simultaneous bartering of goods. Ordering mechanisms with accompanying backlogs and variable delivery delays together with inventory fluctuations provide a flow of information that facilitates adjustment to disequilibria in commodity supplies and demands.

These mechanisms are visible hands, represented by specialized classes of economic agents, guiding and constraining transactions among firms and households. They are the conduit for market forces: they are the market, which is thus seen to be a collection of agents (bankers, brokers, salesmen, merchants, etc.) who must adapt more or less like producers and consumers.

The consequences of this conception of markets as agents mediating transactions in disequilibrium can only be guessed, for their derivation lies in the future, perhaps along lines begun in the promising work of Jean-Pascal Benassy inspired by the neo-Keynesian ideas of Clower and Leijonhufvud, and perhaps indeed certainly containing some of the ingredients from Forrester's industrial dynamics and his national economic model currently under development.

The instruments of government policy, like market mechanisms are exercised by agents (or agencies) who must likewise adapt to information feedback from the system as a whole. Government agents therefore perform according to procedures that are made up of

the adaptive functions (observing, storing, processing, planning, implementing) and that are governed by determined homeostasis or explicit optimizing rules more or less like those operating in other economic spheres. It is thus not difficult to understand why economic policy, formulated and exercised as it must be by adapting humans, may merely add to instead of alleviate instabilities and inefficiencies already present in the system.

Salient Results

The adaptive approach has been the basis for a wide variety of modelling studies, and space limitations preclude even a brief synopsis here (though the interested reader may again be referred to Day and Groves and Day and Cigno). We must, however, survey some salient properties exhibited by certain models of this genre.

Inertia and Rapid Change

Static economic thinking often leads the economist to view the economic system as changing slowly and sluggishly toward optimum conditions and to recommend policies to accelerate adjustment. Adaptive models incorporating behavioral rules, such as cautious optimizing, information lags, and adjustment delays explicitly describe the inertia governing economic behavior. They explain how changes in any one short time interval are limited. Nonetheless, study after study has shown that with the passage of time quite drastic changes are brought about, even though short-run movements are modest.

For example, Cyert and March's behavioral duopoly model explained how an ex-monopolist's market share fell from 80% to 45% in about a quarter century. Other recursive programming examples explained the transition of backward regions or countries to a developed status with a massive migration of rural peoples to urban areas (Day 1968, Fan and Day) in the span of only a decade or two.

Explicit attention to disequilibrium dynamic processes consequently leads to a different perspective than obtained in static analysis. Instead of comparing the economy at one point in time to an equilibrium state, one focuses on the accumulation of short-run, inertia-bounded changes out of equilibrium. The impression obtained from this point of view is one of great and often rapid change after only a few years. Certainly, a generation, and often even a decade, is adequate for producing pronounced alterations in commodity patterns and production technology, even though change at any one time appears to be sluggish.

Now, change produces many "externalities." People are required to accommodate themselves to changing occupations, changing locations, and often to changing life styles. Such adaptation is achieved more readily by some than others. Moreover, various new imbalances are created even when old, "uneconomic" activities are dying out.

The consequence is severe, short-run but persisting adjustment problems. It may well be that much less attention should be paid by policymakers to accelerating adjustment and much more attention paid to controlling its speed and diminishing its costs.

Phases of Economic Change

The picture of economic activity which adaptive models often give is of a sequence of more or less distinct periods of development characterized by distinct sets of resource scarcities and productive activities and distinct qualitative characteristics of change (growth, cycles, stationarity, etc.). Such distinct periods do not come in some fixed or immutable order, as proposed by the stage-making theories of economic history. Rather, they come in a variety of orders and types that depend on the initial technological and behavioral conditions of the economy in question. They also depend on the economy's peculiar parameters of geography, technology, and culture.

Disequilibrium Trajectories

A consequence of the multimode, multiphase, overlapping wave character of solutions to adaptive models is that solution trajectories often exhibit trends that reverse themselves and have the character of moving away from their final equilibrium values or trends much of the time or perhaps even almost all the time until some threshold or watershed period is reached. If this is also a characteristic of real economic systems—as I think it is, then it means that information about the past behavior of such systems available at any given point may deceive one as to future system performance. In this case econometric meth-

ods based primarily on fitting single phase systems of equations derived from equilibrium theory to time series data would provide extremely misleading forecasts of future directions of change in the system.

Natural Resources Policy

The physical durability of natural resources imposes a dynamic structure on resource allocation more or less analogous to that imposed by the durability of capital goods. Resource economics therefore requires dynamic analysis. We can, of course, extend to this field the basic concepts of equilibrium, recognizing that time adds a new, essentially infinite dimension to the characterization and existence of equilibrium. Using appropriate tools (optimal control, differential games, Hamiltonian dynamics), the past or future can be described as an optimal trajectory, as, for example, in Vernon Smith's imaginative rationalization of the Megafaunal extinction.

As much as these and other superb examples of good economics are to be admired, they cannot be followed blindly in erecting the economics of natural resource policy. Too many issues fundamental to the formulation of such policy are entirely glossed over by these contemporary, dynamic embodiments of neoclassical, equilibrium thinking. Among these fundamental issues are three upon which I wish to comment here: the problem of intergenerational exchange, the problem of overshoot, and the problem of surprise.

Intergenerational Exchange

The first point to be considered is that all economic transactions in reality are among members of the existing population. None involve agents not yet brought to life. Current decisions will come to constrain those not yet born and they may be based on farsighted plans, but the agents who make them are unlikely on the face of it to be able to generate decisions that lie on optimal trajectories even if they can be properly defined. Defining them properly, when we recognize that agents die and their numbers and organization evolve, is a matter that raises questions of a morally profound and scientifically baffling nature that are just beginning to receive attention. Certainly the comparability of the utility of agents of differing generations, implicitly assumed in applications of dynamic optimization, has got to strain the credulity even of Frank Ramsey's most ardent admirers when it is applied to the generational exchange problem involved in natural resource allocation. But it is possible that farsighted planning, combined with time preference, is a necessary precondition for growth, while having as its inevitable consequence the rapid exhaustion of resources and the imposition of declining fortunes for some members of the present and future generations. This is a conjecture whose theoretical analysis should have an important bearing on how we analyze resource policy.

Overshoot

If the current generation of economic agents does not know what the equilibrium trajectory is, or perhaps even how to define it properly, and if the dynamics of the system as a whole is strongly influenced by rules of behavior, then it is possible that population and levels of well-being sustainable for long periods of time will be exceeded, then followed by a fall in numbers and a perhaps rapid decline in wealth.

This is the spectre raised by the doomesday or neo-Malthusian Cassandras using models of an essentially adaptive character. Its credibility, however, need not be based on a particular adaptive model but on the historical and archeological record. Many cultures and their associated economies have passed away, driven from existence by their more successful competitors, as we see today in the final destruction of primitive peoples or by their internal (necessarily adaptive) resource allocation mechanisms, as has been speculated to have been the case in the classic Maya collapse (Culbert).

Surprise

To sum it all up, adaptive models lead us to expect surprises in the evolution of economic activity whose exact timing and magnitude defy prediction (for otherwise they would not be surprises). Instead of focusing on economic efficiency, policy should perhaps be aimed at preparing for surprises, not predicting them—which is a contradiction in terms. The way this is done in individual living organisms (Canon), in animal and primitive human societies (Wynne-Edwards), or in complex business firms (Cyert and March) is to allow

for slack, which, in essence, means surplus resources, redundancies, or less than maximal growth.

An example that has been used in this century is the maintenance of surplus stocks for stabilizing agricultural prices. The costs in terms of reduced efficiency lead to attacks on, and indeed a reduction in, the use of this mechanism. But the absence of stocks may lead to severe hardships in the future, just as overproduction in the Sahil has led to the exhaustion of surplus grazing resources with catastrophic implications for the dependent populations.

Another way surprises are prepared for is through knowledge: the accumulation of facts, theories, and operational methods that may be used to generate new rules of behavior, new forms of organization, new chemical and biological processes, new physical mechanisms for controlling the environment when and if they are needed or desired. Certainly the attempt to discover and apply new knowledge can be induced. The knowledge to be accumulated as a defense against surprise, however, surely cannot be induced by surprising events—another contradiction in terms. Instead, that kind of knowledge must be pursued without a goal, without identifiable economic motive just as, according to evolutionary theory, the planning mind itself is generated without a plan.

A Final Comment

A basic principal of survival for the adapting economy must surely be to learn from the past—for it is the only way to learn—but allow plenty of room for surprise. The way to allow plenty of room for surprise is to conserve resources and to create knowledge.

Possibly, and I do not think it impossible, the best way to conserve resources and create knowledge is to allow market forces (recognizing that they work out of equilibrium under the control of adapting agents) to allocate natural resources as best they can and accept the associated costs: the destruction of primitive cultures, the accelerated extinction of many nonhuman species, natural degradation, and the mad pursuit of Philistine values, for these costs may be lower than those imposed by further economic engineering.

Possibly instead, and my instincts as well as my intellect side with this view, the best way to conserve resources and create knowledge is not yet known and will require economic invention and engineering of a high order of sophistication involving the role of the intellect in the evolution of humanity and its forms of organization. If this is so, it will surely involve the development of new institutions for maintaining slack and new forces for motivating present decisionmakers to endow themselves and their descendants with unexploited or embodied natural resources and a knowledge of the past. This accumulation of historical knowledge has brought humanity where it is now, and only with the future accumulation of both resources and historical knowledge can mankind's further evolution be assured.

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Scarcity and Growth Reconsidered

V. Kerry Smith

Faced with historical evidence of persistent growth in the demands for material goods together with the apparent fixity of the natural resource base, it is hardly surprising that policymakers and economists alike periodically reexamine the implications of resource availability for economic well-being. While examples of this pattern are easily cited over the course of U.S. history, the concern evidenced after World War II—with two presidential commissions addressing resource issues (Paley and Cooke)—has had an important impact on our present thinking. As a result, in part, of the issues raised in these commissions, Resources for the Future was established. Shortly thereafter, Harold Barnett and a team of researchers initiated an important series of studies of natural resource scarcity. The culmination of these efforts was a study, *Scarcity and Growth: The Economics of Natural Resource Availability*, by Harold Barnett and Chandler Morse. This study traced the roots of intellectual concern over the availability of natural resources, reviewed the models of economic activities and their treatment of natural resources, and evaluated the trends in their "real unit costs" and relative prices over the period 1870 to 1957. The Barnett-Morse conclusions indicated that, except for forest products, there was no evidence of increasing resource scarcity. Thus, their analysis offered more general support to a similar position advocated by Schultz some ten years before the publication of the Barnett-Morse book. Contrary to the recommendations of the Cooke Commission, he concluded that agricultural land had been of declining importance in the maintenance of economic well-being. Specifically he observed that ". . . the economic developments that have characterized Western communities since Ricardo's time have resulted in improved production possibilities and in a community choice that has relaxed the niggardliness of Nature. As a consequence of these developments, agricultural land has been declining markedly in its economic importance. Will it continue to do so? Existing circumstances in the United States indicate a strong affirmative answer. Nor is the end in sight" (p. 740).

There is now a renewed interest in the issues associated with natural resource scarcity and in Barnett and Morse's results. Are they relevant to today's circumstances? This paper proposes to analyze this question. Section two develops the logical underpinnings of the Barnett-Morse work and discusses an evaluation of them within a simple general equilibrium framework. The third section summarizes some empirical work which updates and reconsiders their findings. The last section discusses the implications of this analysis and its relationship to the definition of natural resources as well as to economists' conception of their role in economic activities.

Measuring Natural Resource Scarcity

Scarcity is a concept so fundamental to economic analysis that it is often left undefined in considering problems associated with natural resource availability. Accordingly, it may be useful to review first principles. Economics is concerned with the problems arising when a society uses the means at its disposal to satisfy its desired ends. Scarcity reflects the limitations of some of these means, and therefore, an inability to satisfy all of the ends. Under such circumstances, it is necessary to consider the characteristics of the processes involved in allocating those means to achieve the desired objectives. Modern treatments of economics recognize that these allocation processes depend on both the purposes of the society and the resource endowments and the technology available to achieve them.

At a general level it would seem possible to distinguish two conceptual approaches to analyzing the role of natural resources, the structural and the outcome methods. Under

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the structural view, a judgment on the relative scarcity of natural resources requires an investigation of their role, directly and indirectly, in each of the production processes for goods and services desired by the community at large, as well as an appraisal of the nature of demand for them. This information would permit the analyst to mimic the functioning of perfect markets in judging the scarcity of natural resources.

The second approach, the outcome method, assumes that it is possible to provide an answer to the scarcity issue by examining the outcomes of all the complex processes modeled in the first strategy. Fisher has aptly summarized the properties of an ideal scarcity index of these outcomes observing that "a measure of a resource's scarcity should have just one essential property: it should summarize the sacrifices direct *and indirect,* made to obtain a unit of resource" (p. 5). Barnett and Morse seem to have had these objectives in mind. We shall suggest, in what follows, that Barnett and Morse's analysis adopts a classical position arguing that there exists a set of positive or predictive prices.

Barnett and Morse: A Classical View

Barnett and Morse measured the importance of natural resources to economic processes in specific terms. Their view of the problem required that some objective measure of resource availability be developed. As a result, they defined a measure of this importance as the real resource requirements necessary to obtain a unit of extractive output, or the "real" unit cost.

In arriving at this choice, they began with the development of three modeling perspectives, Malthusian, Ricardian, and Neo-Ricardian. The first holds that resources are available in finite stocks of essentially homogeneous quality and known quantity. The second emphasizes the variety of quality levels with potentially unknown limits to the quantities of each. The last, developed by Barnett and Morse from the first two, focuses on the services provided by natural resources and the difficulty in obtaining them. It considers ". . . the resource problem as one of continual adjustment to an everchanging economic resource quality spectrum. The physical properties of the natural resource base impose a series of initial constraints on the growth and progress of mankind, but the resource spectrum undergoes kaleidoscopic change through time. Continual enlargement of the scope of substitutability—the result of man's technological ingenuity and organizational wisdom—offers those who are nimble a multitude of opportunities for escape" (p. 244). What is important, for our purposes, is how such conceptions were translated into a testing procedure capable of interpreting the historical evidence.

Since Barnett and Morse sought an objective indication of what the prices for natural resources should be, rather than simply a reflection of the market interactions, it is not surprising that they selected a classical modeling framework.[1] This paradigm contrasts with a neoclassical interpretation of Fisher's definition which would require that consideration be given to the effects of both tastes and technology. That is, the classical view of postulates a one-way causality. Buchanan makes this point, clearly observing that in the classical model "relative costs determine normal exchange values. Implicitly, the theory assumes that predictions about production relations, the ratios of inputs to outputs, are considerably more accurate than predictions about demand patterns. . . . Objective, external measurements can be introduced which should yield predictions about normal exchange values. . . . Exchange value tends to equality with objectively-measurable cost of production" (p. 3). Eagly also supports this interpretation, noting that "Ricardian natural price is a cost-of-production concept in which commodities exchange with one another according to the relative quantities of inputs used in the production of each" (p. 51). Under the neoclassical view, there is no objective measure of what prices ought to be. Prices simultaneously equal the marginal cost to suppliers of the last unit exchanged and the marginal benefits to demanders for that unit. Thus, "neither the marginal evaluation of the demanders nor the marginal costs of the suppliers . . . can be employed as a basis for determining prices. . . . There is no 'theory' of normal exchange rates with positive content here. The analysis provides an 'explanation of results, a logic of interaction . . .' " (pp. 85–86). The relevant issue in evaluating the use of scarcity indexes for appraising the adequacy of natural resources remains the extent to which they are

[1] My own appreciation of this perspective was only developed through an extensive set of correspondence with the authors, Harold Barnett and Chandler Morse.

capable of reflecting all aspects of taste and technological influences to the process of exchange.

Scarcity Indexes in a Simple General Equilibrium Model

The most direct means of evaluating the properties of alternative scarcity indexes is to analyze their behavior in a comparative static framework. It should be acknowledged that exhaustible natural resources introduce some unique problems for judging the properties of a market allocation. (See Stiglitz for a discussion of the implications of market failures for the allocation of exhaustible resources.) However, to begin we shall abstract from these considerations and evaluate the determinants of the rate of change in relative product and factor prices, along with one of the Barnett-Morse real unit cost indexes. The model is adapted from one developed by Jones. We shall maintain the following assumptions:

(*a*) There are two final goods (E and NE) and one pure intermediate good, capital (K).

(*b*) There are two factor inputs in the production processes for each output. They are labor (L) and natural resources (N).

(*c*) Production functions in all activities exhibit constant returns to scale with diminishing returns to factor proportions.

(*d*) There is full employment of resources, perfect mobility, and no factor market imperfections.

(*e*) Each commodity is intensive in the use of a given factor at all levels of factor prices, and no two commodities have the same factor intensities.

(*f*) There is perfect competition in the product and factor markets.

Clearly, these conditions are quite restrictive and are adopted to reduce the analytical detail to a manageable scale. Nonetheless, it is possible to evaluate the features of demand and supply that affect the various scarcity indexes. The analysis is fully developed in Smith. A summary comparison of the rates of change in three candidate scarcity indexes—the relative price of natural resource commodities, the relative prices of natural resources as inputs, and one variant of the Barnett-Morse "real" unit cost indexes (the gross labor requirements for a unit of extractive output)—is presented in equations (1) through (3) below. They are derived by evaluating the changes necessary to sustain an equilibrium when one or more parameters affecting the decisions of the relevant economic agents changes. For example, the supply conditions include full employment constraints for each factor expressed in terms of the equilibrium factor input requirements of each sector and the equilibrium pricing conditions under the maintained conditions of perfect competition. The observed responses in supply must equal those of demand if market equilibrium is to be maintained.

$$(1)\quad (P^*_E - P^*_{NE}) = \frac{(N^* - L^*) + (\bar{R}_N - \bar{R}_L) + (\bar{R}_{KN} - \bar{R}_{KL})}{|\lambda|(\epsilon_D + \epsilon_T)} + \frac{(\epsilon_{IE} - \epsilon_{INE})I^*}{(\epsilon_D + \epsilon_T)} + \frac{\epsilon_T[(T_{NE} - T_E) + (\tau_{KNE} - \tau_{KE})T_K]}{(\epsilon_D + \epsilon_T)},$$

$$(2)\quad (w^* - r^*) = \frac{(N^* - L^*) + (\bar{R}_N - \bar{R}_L) + (\bar{R}_{KN} - \bar{R}_{KL})}{|\theta||\lambda|(\epsilon_D + \epsilon_T)} + \frac{(\epsilon_{IE} - \epsilon_{INE})I^*}{|\theta|(\epsilon_D + \epsilon_T)} + \frac{\epsilon_D[(T_{NE} - T_E) + (\tau_{KNE} - \tau_{KE})T_K]}{|\theta|(\epsilon_D + \epsilon_T)},$$

and

$$(3)\quad C^* = a_{LE}(w^* - r^*) - \bar{T}_{LE} - b_2 T_K,$$

where * designates the rate of change in the relevant variable; P_E is the price of final good that is intensive in natural resource inputs (N); P_{NE} is price of final good that uses little of natural resource inputs; N is level of natural resource inputs available; L is level of labor inputs available; $\bar{R}_N$ is non-neutral rate of technical change, holding factor prices constant, reducing needs for N in both final goods sectors; $\bar{R}_L$ is non-neutral rate of technical change, holding factor prices constant, reducing needs for L in both final goods sectors; $\bar{R}_{KN}$, $\bar{R}_{KL}$ are similar to $\bar{R}_N$ and $\bar{R}_L$ but relate to the rate of reduction in the needs for N and L in the production of K; ϵ_{IE}, ϵ_{INE} are income elasticities of demand for E and NE respectively; ϵ_D is elasticity of demand for final goods—a composite measure of price responsiveness of each final good's demand to relative price changes; ϵ_T is elasticity of final good substitution along the product transformation curve; $|\lambda|$ is determinant of the matrix of the proportions of the gross amount of each primary factor (L and N) used in the production of

each final good (E and NE); $|\theta|$ is determinant of the matrix of the gross relative share of each primary factor (L and N) used in the production of each final good (E and NE); T_{NE}, T_E are rates of neutral (across-factor inputs) technical change on goods; and denote the rate of reduction in unit costs for goods NE and E, respectively, due to changes in technology; T_K is neutral effects of technical change in the production of K; τ_{KNE}, τ_{KE} are net relative shares of the total costs due to K in the production of NE and E, respectively; w is wage rate for labor; r is price of natural resources; $\bar{T}_{LE}$ is rate of technical change affecting labor in the extractive sector; a_{LE} is function of net share of total costs of each factor in production of E and K and partial elasticities of each factor in production of E and K ($a_{LE} < 0$); and C is gross labor requirements per unit of extractive output (E).

This formulation permits direct comparison of the implications of nonzero extraction costs and "degrees" of processing on the properties of relative prices as indexes of resource scarcity. That is, P_E can be treated as a processed natural resource product or as the natural resource with nonzero extraction costs.

A comparison of equations (1) and (2) suggests that the choice of the prices of finished or semifinished natural resources versus rents for the resource *in situ* is a matter which rests solely on the issue of resolving what we are interested in. Each term in these equations can potentially impact the rate of change of prices differently. However, this is to be expected, given the relationship between each set's demand functions (i.e., final versus derived demands). By contrast, the Barnett-Morse real unit cost indexes is not independent of values and, moreover, will not necessarily agree with either factor or product price movements.

Thus, with theoretical analysis it has been possible to isolate the difficulties with the classical mode of analysis. There is no objective measure of what prices "ought to be" independent of the influences of taste. If the outcome method is selected, a comparative static analysis favors the use of relative prices to judge resource availability. Moreover, the verdict from an analysis that reflects the intertemporal effects of alternative resource allocations does not alter this conclusion (see Fisher, Heal). It should be noted that our conclusion refers to ideal conditions. Once we move from this simple analytical structure to aggregate classes of extractive outputs, there is an enormous "leap of faith" required to make the passage. There are any number of reasons for doubting the outputs of such an exercise including the problems associated with aggregation, the implications of nonmarket institutional influences to resource allocation (which have been extensive in the extractive sector) (see Page), and, finally, the time period subject to study itself. On this last issue, there have been dramatic changes in the products, processes, and social institutions in the first seventy-four years of the twentieth century, all of which most certainly can be expected to impact simple inspections of the trends in the relative prices of extractive outputs.

One of the most obvious cases of violations in the assumptions of the general equilibrium model arises for the tax laws governing resource allocation in the extractive sector. Changes in taxes on an input over time will distort the pattern of price movements. In addition, if the incidence is such that the price of the natural resource input is different to individual sectors, then it imposes a distortion on resource allocation. Such distortions can readily be seen, in a comparative static framework, to induce an aberration in the price-output response relationship and, therefore, in relative prices as a scarcity index. See Smith for further discussion.

A Reevaluation of Relative Price Trends

While we have argued that there were theoretical grounds for questioning the results of an outcome-based evaluation of natural resource availability, in the final analysis appraising the importance of these issues involves considerable judgment. A theoretical appraisal alone provides an incomplete view of the relevance of the Barnett-Morse findings for current conditions. It is also necessary to replicate their empirical analysis with more recent information. In what follows, we summarize the principal findings of a reappraisal of trends in the relative prices for the extractive sector as a whole and three subsectors, agriculture, minerals, and forestry. Our empirical analysis has been confined to the period 1900 to 1973. Robert Manthy, of Michigan State University, has updated the Potter-Christy data and has indicated in private correspondence that the data prior to 1900 are inferior to those after 1900.

Table 1. Trends in Relative Prices of Extractive Outputs

Sector	WPI Deflator Linear Regression	BDE Test[a]	CPI Deflator Linear Regression	BDE Test[a]
All extractive	positive trend coefficient, statistically insignificant	1926–1930 (forward) none (backward)	negative trend coefficient, statistically significant	1915 (forward) 1932–1935 1946–1956 1916 (backward) 1920–1926 1933–1956
Minerals	positive trend coefficient, statistically insignificant	1916–1954 (forward) 1911–1958 (backward)	negative trend coefficient, statistically significant	1917-1945 (forward) 1949–1950 1918–1958 (backward)
Agriculture	negative trend coefficient, statistically insignificant	1916–1943 (forward) 1926–1932 (backward)	negative trend coefficient, statistically significant	1915–1916 (forward) 1919 1947–1951 1940–1956 (backward)
Forestry products	positive trend coefficient, statistically significant	1947–1950 (forward) 1941–1951 (backward)	positive trend coefficient, statistically significant	1916–1951 (forward) 1967–1971 1927–1947 (backward)

[a] Indicates statistically significant (at the 10% level) departures from the mean value line.

While the Barnett-Morse analysis of the movements in their indexes of resource scarcity was largely an informal inspection of the trends in the relevant data series through graphical inspection, a linear trend analysis with the updated relative price data confirms their conclusions. That is, the estimated trend equations using either a wholesale price deflator (base = 1947–49) or the consumer price index (base = 1967) indicated no statistically significant positive association between the relative prices of minerals, agriculture, or the full extractive sector and the time variable. Moreover, using the CPI deflator, the estimated trend coefficients are negative and statistically significant. In both cases, the forestry sector yields a positive and statistically significant estimated trend coefficient. These findings are reported in the second and fourth columns of table 1.

On the basis of this evidence, it is tempting to conclude that little has changed since the first Barnett-Morse appraisal. However, this interpretation of the empirical findings may well be too strong. Barnett and Morse sought to examine whether there was a consistent long-term movement in the relative prices of extractive outputs. These tests implicitly assume a constant coefficient time-trend model is sufficient to evaluate this hypothesis. An essential component of a more complete test of increasing resource scarcity must focus on the stability of the model used for testing hypotheses concerning the trend coefficients. In order to evaluate this question, the estimated models for each sector were tested for the stability in the parameters of the trend model.

The Brown-Durbin-Evans' (BDE) cusum of squares statistic (S_k) is based on the premise that shifts in a model's structural coefficients will be reflected in the residuals from the estimated model. The statistic is defined as

$$(4)\quad S_k = \frac{\sum_{t=l+1}^{k} \hat{u}_t^2}{\sum_{t=l+1}^{T} \hat{u}_t^2}, k = l + 1, \ldots T,$$

where l is the number of coefficients to be estimated, T is sample size, and $\hat{u}_t$ is recursive residual estimates. (For more details, see Brown, Durbin and Evans, and Smith.) The cusum of squares test consists in constructing a confidence interval for a predefined significance level about an expected value line and evaluating whether or not the estimated S_k lie outside the interval.

The third and fifth columns of table 1 report the results of these tests indicating the periods in which S_k lies outside a 10% confidence interval. Since sample positioning can influence the test's results, the table reports both forward and backward recursions.

Overall, these results suggest that the conclusions of a simple trend analysis can be misleading. All models are unstable over the period studied. There is not a single pattern of price movements, but potentially several. Given the simplicity of the model and the degree of aggregation, these findings are hardly

surprising. However, they do imply that the trend movements in relative prices should not form the sole basis for a judgment on natural resource availability. Thus, our empirical findings reinforce the theoretical misgivings over the ability of an outcome approach to provide sufficiently discriminating information to enable a judgment on natural resource scarcity to be made.

Implications

Scarcity and Growth was an important book both for the questions it raised and the insights offered as to the process through which materials constraints might be relaxed over time. Unfortunately, its methodological underpinnings were never fully appreciated by most of the economists and policymakers who used the results. Barnett and Morse used real unit cost as a measure of the objective or "natural" prices discussed by classical economists. Their reasons for presenting several unit cost indexes—labor requirements and an index of labor and capital requirements per unit of extractive output—must be understood within the context of the classical model. That is, heterogeneous factor inputs introduced difficulties in the classical model. The problems associated with Barnett and Morse's unit cost indexes parallel the limitations of the classical model. (See Brown and Field, and Smith for more details.)

While *Scarcity and Growth* identified many of the questions which need to be considered in evaluating natural resource availability today, it does not seem to hold the methodology. This conclusion is based both on the theoretical and empirical analyses discussed in this paper and some more general issues identified in Smith and Krutilla. Briefly, their critique centers on the definition of natural resources which has been adopted in most of the conventional literature, including *Scarcity and Growth*. It restricts them to only those commodities exchanging on private commodity markets, thereby excluding the whole range of environmental common property resources. This omission is important to the evaluation of natural resource scarcity. The focus on private market transactions alone ignores the fact that some resolutions of a materials scarcity may usurp the services of one or more of these common property resources that do not appear through market exchanges. As a result, there is a potential for bias in the past economic evaluations of resource availability.

Scarcity and Growth offered an agenda of research issues in its carefully articulated analysis of the role of natural resources in a changing world. Unfortunately, these elements in the Barnett-Morse contribution have been overlooked in past discussions of their findings. The analysis reviewed in this paper suggests that they may offer important components in the research agenda necessary to reevaluate the potential for resource and environmental constraints to the maintenance of economic well-being.

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Discussion

Alan Randall

This session has focused on some major issues in natural resource economics. The papers, while quite diverse, have a common theme in their concern for the long-term prospects for civilization, insofar as those prospects are influenced by current natural resource allocation decisions with long-lived consequences. We have been blessed with three excellent papers, all exhibiting the highest levels of professionalism and all without major errors. My comments, for the most part, are intended to provide additional perspective and, on occasion, to identify issues which remain unsolved.

Richard H. Day's criticism of the conventional, neoclassically-based economic way of thinking is much to the point. The adaptive models of which he speaks bear much more similarity to real world decision situations, and it is clear that these models yield some interesting insights into problems which have long puzzled natural resource economists.

Day focuses on adjustment processes. Searching for the roots of this approach, he reaches back into the nineteenth century for evidence that seminal neoclassical economists had similar foci. However, such evidence is mixed, at best. While it is true that the Walrasian tatonnement is a groping adjustment process, Leon Walras seemed to expect that equilibrium eventually would be achieved. Alfred Marshall recognized adjustment problems, but concentrated mostly on analysis of equilibrium states.

Rather than these early neoclassicals, it seems, the intellectual precursors to adaptive economics must be found elsewhere. Adaptive economics is evolutionary, but it rejects cruel, mechanistic social Darwinism. Its elemental unit of analysis is the transaction. Its time focus is sweeping and its analytical outputs are trajectories tracing the secular rise and fall of activities, firms, industries, and (there is no reason why not) institutions. Thus, its intellectual roots lie not among the early neoclassicals, but with John R. Commons.

Commons' system was a detailed and, in many ways, valid description of the real world. As a model, it failed to find favor with mainstream economists not because it was faulty—it wasn't—but because it was not well adapted to the analytical technology of the economists of its day: geometry, algebra, and calculus. Now, Day brings to Commons' system a mathematical programming technology which has much greater potential of operationalizing it.

Commons' system was descriptive but, being basically insoluble, not predictive and not especially explanatory since it did not readily yield testable hypotheses. It seems fair to raise the question as to whether Day's system might not have some similar disabilities. Day indicates that it is not a predictive system and should not be, since surprises are to be expected and the past is a poor predictor. If adaptive economics cannot predict, can it explain? Day's models can be made to track or mimic, if you will, the past; but, is that the same as explaining either the past or the underlying system?

Regardless of the answer to the above question, adaptive economics provides a useful way to conceptualize problems, as is clear from Day's perceptive discussion of natural resources issues in the closing pages of his paper.

Let us now move to Kerry Smith's reconsideration of the resource scarcity question. The inquiry into resource scarcity by Harold Barnett and Chandler Morse (B and M) arrived at a conclusion which was most congenial to the conventional wisdom of its day. Their finding of no evidence that exhaustible resources were becoming more scarce was consistent with the pervasive optimism of the Camelot years when it seemed to be widely believed that an age not only of plenty but also of social justice was just around the corner. It was consistent with the view of what may be called the late-neoclassical era of economic thought that land (broadly defined as natural

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resources) had no special importance in production; on the input side, one should focus only on labor and capital, including, as T. W. Schultz insisted, human capital. Not surprisingly, the B and M study was received uncritically by the profession.

Smith shows that the B and M concept of resource cost is inadequate. First, it is an inadequate concept of costs, and second, cost is an inadequate indicator of scarcity. Smith also shows that the statistical methods of B and M are rather too gross to identify inconsistencies in trends across time sub-intervals in their period of analysis. Thus, the quite sweeping conclusions of B and M cannot be accepted uncritically.

Smith then corrects these deficiencies by deriving a concept of scarcity within a general equilibrium context, and examining the market for extractive resources over the period 1900 to 1973, using more sensitive statistical methods. He finds that the statistical models are unstable over that time period. While, in very broad brush, his findings are not hugely different from those of B and M, his interpretation is different: the empirical findings offer no consistent evidence about patterns of scarcity of exhaustible resources over time.

More fundamentally, however, the conceptual underpinnings of Smith's improved "outcomes" model of scarcity, while more defensible than those of the B and M model, are inadequate to address properly the question of increasing scarcity. This will be no revelation to Smith; he is very much aware of it.

Prices reflect resource rents, which ought to increase as scarcity becomes more pronounced, but costs of extraction, transportation, refining, marketing and, often, processing also ought to increase. The fact that we have achieved ever increasing production efficiency in resource extraction should hardly convince us that exhaustible resources are becoming less scarce. The fact that we are ever more effective at exhausting our resources should not convince us that, in some real sense, our resources are inexhaustible (which is, after all, the implication of the models I have characterized as late neoclassical). The net resource price concept, which Robert Solow and others have introduced to modify the Hotelling model of resource extraction, while a conceptual improvement, is empirically quite elusive.

It seems that we remain pretty much in the dark, in our quest for useful data about resource scarcity. Common sense tells us that stocks of many resources are diminishing, and that much of our technological progress has not, as some would have us believe, expanded the dimensions of "spaceship earth" in ways most useful for human existence. Rather, it has enabled us to increase the rate of resource exhaustion, making ever larger transfers from future generations to ourselves. On the other hand, developments which enable us to substitute more plentiful for less plentiful resources, to substitute flow resources for stock resources, and to discover feasible uses for things not now recognized as useful resources, promise some relief from the problem of resource scarcity. In other words, the rate of diminution of known stocks of currently useful resources is not an adequate indicator of resource scarcity. Smith has not solved this conundrum for us, but he has provided us with a more adequate understanding of why we do not know the answers.

Finally, Smith has made an important contribution by pointing out that exhaustion of extractive resources, if it is a problem, is only part of the problem. Thus, study of the movement of market indicators of the value of market goods cannot even address an at least equally important problem, the degradation and depletion of life-supporting indivisible and nonexclusive goods.

The contribution by John Ferejohn and Talbot Page provides an especially elegant proof of a rather obvious proposition. This observation is not intended to belittle their efforts. Elegance is much to be praised. And, proving obvious propositions is not a waste of time. The history of ideas is replete with instances of "obvious truths" which proved unable to withstand test.

Any discounting rule necessarily requires that the present generation is a dictator. This is but a single application of a more general theorem (awaiting elegant proof). Any rule for allocative decisions with multigenerational consequences must necessarily place the present generation in a dictatorial role.

J.M. Keynes' cavalier dismissal of the future ("in the long run, we are all dead"); William Baumol's suggestion that altruism on the part of present generations seems uncalled for, since history suggests that future generations will be richer than we are; the concern of John Krutilla, E. J. Mishan, and others, that we are on the one hand robbing future generations of exhaustible treasure and, on the other,

burdening them with perpetual care of almost indestructible wastes; the neoclassical argument that the power of bequest gives the present generation sufficient stake in the future; and the concern expressed by myself and probably many others that for present generations, the welfare of future generations is a non-exclusive good (a collective good in the sense of Mancur Olson) and thus will almost certainly be underprovided relative to the efficient level as seen from the perspective of the present generation: all these arguments assume the dictatorship of the present and address themselves to debate among the enfranchised of the present as to what provisions ought be made for the disenfranchised of the future.

Let it be understood that the present generation, like all dictators, is constrained in many ways: by an opportunity set inherited from the past; and by cultural and constitutional traditions which can be contravened only with the consent of a good many of the more powerful among the governed. Dictators always have limited information on which to base decisions about matters concerning their subjects. The subjects of present generations are future generations, so the information problem is geometrically expanded. Further, unlike other dictators, the present generation is not a monolith, but a diverse body politic with access only to imperfect methods of making decisions even concerning matters which affect only itself.

Thus, what is needed is a method which permits present generations to make reasonably competent and fair decisions affecting the future. Ferejohn and Page express the intention of pursuing this goal through an axiomatic analysis of the implications of intergenerational fairness. One hopes they will be successful. Nevertheless, however stimulated one is by the intellectual qualities of the debate led by John Rawls and Robert Nozick, any optimism must be tempered by the observation that axiomatic approaches even to intragenerational fairness have failed to generate answers which satisfy the positivists or command universal assent as normative propositions.

Assume, however, that Ferejohn and Page succeed in developing a rule based on fairness by which to decide issues involving potential impacts many generations into the future. Implementation of that rule must be a voluntary act of present generations, for who is to coerce the present? The present generation, being decisive, would remain the dictator. The quest of Ferejohn and Page, as I understand it, is for a set of axioms which can gain the assent of the present generation (in each succeeding generational time period) on intellectual grounds, and thus convince present generations to voluntarily relinquish the perquisites of their inevitable dictatorship.

The observant reader will notice that I have not said a word in disagreement with Ferejohn and Page. I have tried only to provide a perspective. I particularly applaud the sentiments expressed in the initial and final passages of this paper. The discounting rule, as usually applied in economic analysis, is not just a dictatorial rule but an especially selfish form of dictatorship. How else could one explain the attempt of the present generation to attribute normative significance for all time to the outcome of its current capital markets? I personally would urge upon my fellow citizens of the present generation a policy of deliberate caution, to the point of self-denial if necessary, in the face of opportunities which could open Pandora's box for generations unborn. Special burdens of proof, and demonstrations of overwhelming benefits to the present generation, should be required of such choices. If that makes me a contemporary Luddite, so be it.

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Editor's Note: George Tolley, professor of economics, University of Chicago, was a discussant for this session, but he did not provide a written version of his comments.

Appropriate Technology for U.S. Agriculture: Are Small Farms the Coming Thing?
(Otto C. Doering III, Purdue University, Chairman)

Introductory Comments

Otto C. Doering III

With the advent of Schumacher's book, *Small Is Beautiful,* "small" has become both fashionable and popular. Smallness, indeed, the whole question of scale, is suddenly an important topic again. Schumacher and the other authors who have since jumped upon the "smallness" bandwagon did not create the issue. It reflects some very deep-seated and recurring concerns about size and scale in many of the activities undertaken in the name of modern production systems.

There have long been concerns in agriculture with respect to both scale and the appropriate level of technology. These have been an explicit concern of U.S. public policy for more than a century, some examples being the Morrill and Homestead Acts and, more recently, the effort to enforce the 160-acre maximum in federal water projects. One of the major difficulties in dealing with the issues of scale and appropriate technology is that they combine concerns of equity and of resource use. As in other areas of government concern, policies have been confounded at times by the attempt to meet both considerations simultaneously. Ultimately, the notion of efficiency in resource use is redefined to meet equity considerations.

Today, the most ardent supporters of "smallness" are frustrated by conventional definitions of economic efficiency. There is a feeling that the rules of the game ought to be changed so that small scale operation in agriculture becomes economically viable where it would not have been before. It is not surprising that the new agricultural legislation reflects both the continuing problem of reconciling resource and equity considerations as well as some contradictions between the rhetoric about small scale, family farms and the fact of rather larger scaled production for the bulk of our food and fiber. Such contradictions are not new. One current example is the disaster payments program which encourages the perversity of cultivating continuing crop failures in some regions on land that should be grazed rather than cultivated. Because of equity considerations for some farmers served by this program, there is talk of increasing benefits across the board without considering the basic land use and resource question of public support to maintain marginal acres in production in a time of agricultural surplus.

What is new today is the fervent belief held by many in the new administration that smaller scale agricultural production is both better, by definition, and workable if the sector could just be made to run the way it should. However, little new and practical has been suggested to change whatever scale and technology bias now operates. It appears as though we may have to learn over again that commodity payments, loans, and the other components of our 1960's farm programs that are being reused again today do not result in effective transfers to small scale or low resource farmers, let alone tip any scales in their favor. The payments formula in the new bill is complex enough so that only a limited number of farmers will have the management resources to calculate where they are likely to come out if they participate.

It is difficult to predict what economists will be asked to contribute in this arena now partially filled with advocates of both big and small. There is some important background work to be done and there are some important questions to be asked if economists are to contribute other than by joining sides. First, we need to have some idea where we are today. Little work has been done on size/scale relationships in agriculture in the last decade; and as Gardner and Pope indicate, the impression we have been getting from the agricultural census may well have been misleading. Second, there has to be an understanding of why we are where we are today. Facets of this are addressed by Raup and Barkley, first with respect to the valuation and use of the land resource and second with respect to the influence of technology on the scale and character

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of agricultural production systems. Finally, there has to be some analysis of alternatives and consequences with respect to the type of agricultural system our society desires and to the various routes to get there.

An understanding of why we are where we are requires a broader frame of analysis than that normally adopted by economists. Social and institutional factors are often referred to in this context. One aspect of such an analysis is an examination of the link between the intent of policy and the actuality of its operation. Other factors such as risk management and systems dynamics are often subsumed under their economic effects and deprived of the context which shapes much of their character. As an example, the direct economic trade-off between labor and machinery is only one reference point for the analysis of something like the change to shelled corn harvesting systems. It may be much more useful to consider this change in technology and scale from the standpoints of risk aversion and systems-handling engineering.

The questions that Schumacher raises about economic decision making are important in that they make explicit many decisions about resource use which are never considered explicitly when resource decisions are made. Schumacher argues that implicitly: (*a*) We are now living off of irreplaceable capital—that is, we are expending our natural capital. (*b*) We are pushing natural tolerance limits by using the environment as a pollution sink. (*c*) We are giving too much weight to short-term considerations in resource decision making. (*d*) We value goods at the "market," which ignores our dependence upon the natural world. (*e*) We are increasingly dependent upon enlightened human behavior. (*f*) We have been ignoring the social side effects of scale. He concludes that if politics cannot be left to the experts, neither can economics and technology (p. 158).

It would appear that the most constructive role for agricultural economists would be to focus first on a somewhat narrower set of questions while explicitly recognizing Schumacher's concerns and identifying where they have been critical in shaping current scale and technology. Three such questions would be:

(*a*) How are scale and structure determined in agriculture?
(*b*) How are resources valued in agriculture, and what influence does this valuation have?
(*c*) What requirements does a technology impose upon a production system?

Different technology or scale of operation will be adopted in the future on the basis of changes in circumstances from those under which current decisions were made. It is the task of predicting those future circumstances and also predicting their effect upon technology and scale that is most difficult. The difficult is made almost impossible when we are unsure what future it is that we want. What farm operators might see in their own best interest on an individual basis might be in conflict with the long-term health and viability of an agricultural sector made up of small farm firms. The new tax reform provisions on farmland inheritance might be an example of this. The reforms make it more likely that a family-owned piece of land can be passed intact between generations. In the past, however, new entrants into agriculture found the sale of that portion of the farm necessary to pay inheritance taxes as an excellent opportunity to begin to acquire land. Thus, we may have ruled out the opportunity to purchase modest sized parcels of land for those who have not already established a base or for those who are unable to compete on the land market against established farmers for that reduced number of such parcels that become available and reach the market.

What is evident here is that there is considerable slippage between the hand of economic analysis and the eye of successful policy implementation. Many of those who are convinced that small is beautiful are also sure that they know the path to small scale enterprise and appropriate technology. One's own values may lead to adopting or shunning a "small is beautiful" ethos; this is a matter of individual choice. However, firm believers must be disabused of the notion that there is a straight path and that they know the route. If we do not even know where we are today, how can we be sure of where we will be tomorrow? It is clear that our homework is cut out for us.

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How Is Scale and Structure Determined in Agriculture?

B. Delworth Gardner and Rulon D. Pope

The purpose of this paper is to note and assess recent changes in scale and structure of U.S. agriculture. Census data will be reviewed in the light of hypotheses that have been advanced to explain structure and scale. Our purview will be limited to the farm production sector.

Numbers of Farms and Farm Size

Many view with alarm the reported demise of approximately one farm in four, or about one million farms, during the 1960s. Kyle (p. 1) reports that a "group of fairly conservative agricultural economists . . . expects a continued increase in the concentration of production on fewer and fewer farms. In 25 years, this could result in a nearly complete demise of typical family farms in the units classified as commercial full-time farms."

Recent data, however, suggest that such fears are premature. According to official census counts, the total number of commercial farms decreased from 2.42 million in 1959 to 2.17 million in 1964, and further, to 1.73 and 1.70 million farms, respectively, in 1969 and 1974.[1] These losses represent 10.3%, 20.3% and 1.7% for the periods 1959–64, 1964–69, and 1969–74. One might conclude, therefore, that the number of farms has fallen in recent years but that the rest of decline fell sharply 1969–74.

Two factors suggest that such a conclusion may be erroneous. The 1969 and 1974 censuses counted only those farm units which had gross sales exceeding $2,500, whereas the 1964 and earlier ones included units that had sales above $50. Since the major analytical purpose of census data is to describe various characteristics of a common set of farm units, some definitional change is desirable when commodity price changes have a significant impact on sales, the principal qualifying criterion. But the definitional change, as well as the farm product price escalation of the early 1970s, may have introduced serious bias in census counts of farm numbers.

One way of appraising the impact of the definitional change is to assume that the 1969 definition applied also in 1959 and 1964. If so, the reduction in farm numbers 1959–74 would have been only 370,000 instead of the 720,000 actually reported, since many farms in the earlier years did not have $2,500 of gross sales. On the other hand, the number of farms qualifying in 1974 was substantially expanded because of the product price escalation that occurred in the early 1970s. The price escalation, therefore, had the effect of understating losses in numbers of farms. We are, therefore, left in a quandary. The one factor suggests that 720,000 farms lost is too high; the other, too low. Perhaps the only safe conclusion is that the farm numbers game is a dangerous one to play.

Similarly, escalated prices in the 1970s also preclude the observation that the rate of decline is diminishing in recent years. The index of prices received by farmers for all products stood at 96, 95, 107, and 192 for the years 1959, 1964, 1969, and 1974, respectively (U.S. Department of Agriculture 1976, p. 455). These facts imply that price effects may have been particularly significant in understating farm losses in the 1974 census.

Farm Size and Type

In 1974, the differences in percentages in the various economic classes are not nearly so great as in earlier census years (table 1). The percentage of farms with sales above $40,000

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[1] Computed from *U.S. Census of Agriculture, 1959*, vol. 2, chap. 11, table 5; *1964*, vol. 2, chap. 6, table 15; *1969*, vol. 2, chap. 7, table 17; *1974* printout of preliminary table 31, vol. 2.

Table 1. Percentage of Commercial Farms in Each Economic Class, 1959–74

Value of Agriculture Products Sold	1959	1964	1969	1974
	%			
$100,000 or more	.8	1.4	3.0	9.0
$ 40,000–$99,999	3.4	5.1	9.8	19.1
$ 20,000–$39,999	8.7	12.0	19.1	19.0
$ 10,000–$19,999	20.0	21.6	22.8	18.3
$ 5,000–$ 9,999	27.1	23.3	22.5	17.5
$ 2,500–$ 4,999	25.6	20.5	22.8	17.1
$ 50–$ 2,499	14.4	16.1	[a]	[a]

Sources: Computed from *U.S. Census of Agriculture, 1959*, vol. 2, chap. 11, table 5; *1964*, vol. 2, chap. 6, table 15; *1969*, vol. 2, chap. 7, table 17; *1974*, printout of preliminary table 31, vol. 2.
[a] After 1969, "commercial farm" was redefined. Class VI farms ($50–$2,499) were no longer considered commercial farms.

in 1974 was 28.1, whereas in 1969 it was only 12.8. At the other end of the class spectrum, the percentage below $20,000 sales was 52.9 in 1974, but 68.1 in 1969. Thus, if farm sales only were the criterion of farm size, there was clearly a significant increase in size between 1969 and 1974. This result, however, may be due to increases in pure scale, defined in terms of total inputs committed per farm, and/or to increases in product prices which increased the value of sales even though the quantity of sales may not have increased.

Although much less satisfactory for most purposes, another measure of scale or size is the acreage which is contained in the farm unit. The average commercial farm in 1959 had 405 acres, while the average in 1974 had 534 acres—a substantial increase (table 2). There was only a slight increase, however, between 1969 and 1974, from 530 to 534 acres. This difference is likely seriously biased downwards because of the price escalation effects discussed earlier. This can be seen clearly in the average acreage in farms by type of farm. Between 1969 and 1974, the average acreage in cash-grain farms dropped from 504 to 485 acres. But grain price increases were especially high over this period, which likely pulled many new and smaller farms into this category (see table 3) and thus reduced the average size. For other types, with the exception of

Table 2. Average Acreage of U.S. Commercial Farms by Type, 1959–74

	1959	1964	1969	1974
	acres			
Average for all commercial farms	405	446	530	534
Cash grain	441	465	504	485
Tobacco	90	97	128	129
Cotton	198	256	466	579
Other field crops	272	359	414	478
Vegetables	187	202	236	240
Fruits and nuts	140	154	144	149
Poultry	97	116	130	128
Dairy	208	227	249	276
Other livestock[a]	798	885	828	896
General farms	281	348	449	494

Sources: *U.S. Census of Agriculture, 1959*, vol. 2, chap. 12, tables 53, 78, and 79; *1964*, vol. 2, chap. 10, tables 8, 17, and 18; *1969*, vol. 2, chap. 8, tables 22, 31, and 32; *1974* printout of preliminary table 32, vol. 2.
[a] Includes livestock ranches.

Table 3. Number of U.S. Commercial Farms by Type, 1959–1974

	1959	1964	1969	1974	Percentage of Change 1964–1974	Percentage of Change 1969–1974	Approximate Percentage of Change in Prices Received, 1964–1974 Index
	Number of Farms				%		
Cash grain	398,047	404,253	369,312	580,254	+43.54	+57.12	178
Tobacco	190,057	171,384	89,903	95,493	−44.28	+6.22	68
Cotton	241,849	164,076	40,534	30,725	−81.27	−24.20	65
Other field crops	38,332	35,130	31,190	81,415	+131.75	+161.03	136
Vegetables	21,912	23,207	19,660	19,548	−15.77	−0.57	63
Fruits and nuts	61,419	57,256	53,754	51,270	−10.45	−4.62	4
Poultry	103,279	82,120	57,545	42,690	−48.02	−25.81	50
Livestock and livestock ranches	684,061	580,811	647,884	493,816	−14.98	−23.78	92
Dairy	428,293	366,967	260,956	196,057	−46.57	−24.87	100
General farms	211,613	201.980	126,527	59,654	−70.47	−52.85	100

Sources: *U.S. Census of Agriculture, 1964*, vol. 2, chap. 10, p. 979; *1969*, chap. 8, table 22; *1974* printout of preliminary table 32, vol. 2; *USDA Agricultural Statistics 1976*, table 637, p. 455.

poultry where there was a slight decrease, the trend was to higher acreages between 1969 and 1974, especially in the case of cotton farms.

Much volatility exists over time in the number of farms by type (table 3). The percentage change from 1964 to 1974 was strongly positive for cash-grain and other field crop types and was down for all others. There are several factors that can shift the number of farms by type over time: (*a*) farmers shift cropping patterns when relative prices change and thereby qualify farms in a different type category, (*b*) relative price movement can shift revenues among farm enterprises and thus change the farm type even though acreages may not change, and (*c*) increases in prices may qualify more farms of a given type for inclusion under the census definition. For all of these reasons, one might hypothesize that farm numbers would increase most for those types where relative prices increased most, namely cash-grain and other field crops. This hypothesis is supported by the data.

To support further the contention that price increases significantly distorted farm numbers: contrary to what occurred between 1969 and 1974, a comparison of 1964 and 1969 (when product price increases were modest compared to the later period) shows that all farm types were down in numbers except for other livestock. For this latter type of farm, numbers are unreliable because of the definitional changes over the period analyzed.

Some State Trends

During the period 1964–69, fourteen of the forty-eight contiguous states experienced a rise in the number of commercial farms (classes I-V) and sixteen states experienced a decline in the acreage per farm. Similarly, in the 1969–74 period, fifteen states experienced increases in the number of commercial farms and twelve indicated declining acreage.[2] In many cases, the percentage rates of change reached double digit proportions (particularly in the South).

Given the fact that price increases were modest during the 1964–69 period, it seems to be evident that price effects alone did not increase farm numbers and reduce farm size. Something more fundamental was occurring and we think there was parcelling of farm land into smaller units in some areas. We would hypothesize the location to be concentrated at the urban fringe and the motives to be changing lifestyles and tax avoidance. If we are correct, farms may be becoming smaller and more numerous at lower acreages, but larger and fewer at large acreages. If this is so, we would speculate that the problems faced by the operators of these very dissimilar classes of farms would also be highly dissimilar, and public policy well-suited to one might be highly ill-suited to the other.

Causes of Increased Size

The plethora of hypotheses that purport to explain the trend towards larger farms cannot be evaluated adequately in this brief paper. However, two of the most prominent are pecuniary and technical economies of scale, and government policies—particularly price supports and taxes (see Ball and Heady).

Although numerous studies have suggested that these are the crucial causal forces in producing increased scale, in most cases assertions are made without adequate empirical substantiation. (See Quance and Tweeten, in Ball and Heady, for a review of policies and speculation regarding their impact.) This inadequacy appears particularly true regarding government policies. Several studies have argued that price policy and tax laws yield higher rates of return on large farms than small ones, but we are not satisfied that either the theoretical or empirical rationale is adequate. It is clear that price supports and other government policies reduce risk by truncating the lower tail of the probability distribution of returns. However, the link between these effects and increased scale has never been empirically measured in a *ceteris paribus* world. The impact of price supports might well have been output-increasing, but whether or not the distribution of benefits favors large farms or are proportional to size has never, to our satisfaction, been demonstrated. Clearly, if price supports are coupled with technological progress, there are strong incentives for output increases (and presumably scale) since rightward shifts in supply do not produce correspondingly lower prices (Herdt and Cochrane), especially in the early stages of adoption of new techniques.

The most widely utilized proxy for technical change is the productivity index which rose sharply over the period, with the 1950s showing the largest percentage increase (table 4). The percentage changes in productivity generally follow the percentage changes in farm

[2] Computed from *U.S. Census of Agriculture*, vol. 1, 1969, 1974.

Table 4. Productivity and Farm Size

Year	Productivity Index (1967=100)	Percentage Change	Average Acres/Farm	Percentage Change
1910	53	—	138	—
1920	54	1.8	147	6.2
1930	53	−1.8	151	2.7
1940	62	17.0	167	10.6
1950	73	14.5	213	27.5
1960	92	26.0	297	39.4
1970	101	20.7	373	25.6
1975	113	11.9	387	3.8

Sources: Productivity index, *Changes in Farm Production and Efficiency*, USDA ERS Statist. Bull. no. 548, annual (productivity is defined as output per unit of input); average acres per farm, for 1910–60, Ball and Heady, p. 44; for 1970, 1975, *Agricultural Statistics, 1976*, table 583, p. 417, USDA.

size. The presumption is that technical change is the mechanism that induces both productivity increases and enlargement in farm size. (However, the separate impacts of random environments, e.g., disease and weather, and technical change on productivity, are not understood fully.)

As is well known, input ratios have changed dramatically during recent decades. Productive assets per farm worker and per farm have risen from \$3,300 and \$6,200 in 1940, to \$97,601 and \$163,885 in 1975, respectively (USDA *Balance Sheet*). (Productive assets are defined as real estate + machinery + inventories + cash on hand.) Even in real terms, these are sixfold increases. Further, man-hours in agricultural production have fallen from 20.5 billion hours in 1940, to 5.3 billion in 1975, with a concomitant rise in output per man-hour during the period. At the same time, units of machinery are decreasing, but their values and sizes are increasing. During 1975, PTO horsepower for all purchased tractors averaged 97 compared to 72 for 1970 (USDA *Balance Sheet*). The trend towards increased capital-labor ratios and unit size of machinery is apparently linked to increased farm size through declining average production costs (Rhodewald and Folwell).

The above data are indicative of biased technical progress. After noting that labor's share of income in agriculture declined from .43 in 1949 to .20 in 1968, Lianos argued that these changes were not due solely to increased relative wages that resulted in a substitution of capital for labor but also to technical change that was labor-saving and capital-using as well. One study (Binswanger) found evidence that innovations are induced by relative factor price shifts. He estimated that the relative price of labor to machinery rose only approximately 4% from 1912–1968. Despite this small rise, during the period there was a large increase in machinery demand and apparently innovations that were machinery-biased. However, during the 1970s there have been some dramatic relative factor price movements which may signal future directions of technical change. From 1970 to 1975, the relative prices of farm real estate and machinery to wages rose from 1.52 and .91 to 1.84 and 1.01, respectively. During this interval, the relative price of machinery to land changed little, although land prices doubled between 1971 and 1976.[3] On the basis of this evidence, one might hypothesize that future innovations might well be land and machinery saving. However, we speculate that land prices are likely to fall, reflecting lower anticipated rents (Gardner and Zivnuska), thus removing the inducement for land-saving technology.

In addition, the proper relative price of durables must be reckoned in terms of user cost. Jorgenson's neoclassical investment theory implies that the firm will purchase land until its value of the marginal product equals user cost, (assuming no taxes or depreciation, user cost = interest rate × price of land − capital gains). Given the 1975–76 increase in farm per acre real estate values, user cost would be zero for any interest rate below 12.1%. (Ignoring improvements, 1976–75 farm real estate prices per acre equalled \$403 − \$354 = \$49.) Hence, at current interest rates and land prices, there are incentives to operate land near the extensive margin.

Other Structural Characteristics

In addition to farm size and types, there are other characteristics important to the present discussion. These include tenancy, type of commercial farm organization, residency, off-farm work, income, and debt.

Farm Tenancy

From 1959–74, there was a sizeable increase in the percentage of full-owner farms (43.5% to 53.4%) and a sharp decrease in the percentage of tenant farms (25.5% to 13.3%). The per-

[3] Computed from U.S. Department of Agriculture, *Economic Tables, 1977*, p. 21; and *Agricultural Statistics, 1976*, p. 457.

centage of part-owner farms increased slightly over this period.[4]

Disaggregated by economic class, quite a different picture emerges. The percentage of full owners in the over-$40,000 sales classes did not increase much from 1964 to 1974, but the percentage in the under-$40,000 classes has increased significantly. The percentage of part owners in the over-$40,000 classes, on the other hand, has increased sharply and vice versa in the under-$40,000 classes. Finally, the percentage of tenants has declined sharply across all economic classes. These data support the hypothesis that many of the farmers with large sales are expanding scale by means of renting land to supplement that which they own.

Type of Commercial Farm Organization

Tony Dechant, in his introduction to *The Corporate Invasion of American Agriculture*, by Victor K. Ray, makes what is a fairly representative allegation about corporations "consuming" family farms (p. v). "We in the National Farmers Union believe 'the corporate invasion of American agriculture' by nonfarm interests is real. It is leaving behind 'wasted towns, deserted communities, depleted resources, empty institutions, and people without hope and without a future.' The invasion is still in the beginning stage. Some people see this trend as inevitable—that is, cannot be stopped. Not only can it be stopped, it must be stopped." Here again, in aggregate, the data suggest that this view is exaggerated.

The census classifies farm organization by four groups: individual or family farms, partnerships, corporations, and others. In 1969, 85.4% were classified as individual or family farms; 12.8% were partnerships; 1.2% were corporations; and .6% were other. In 1974, 89.5% were individual or family farms; 8.6% were partnerships; 1.7% were corporations; and .2% were other.[5] Thus, partnerships declined sharply (by 35%), offset by substantial gains in individual or family farms and a slight gain in corporate farms. Even though the percentage increase in corporate farms was 33.2%, they were still less than 2% of total farms in 1974. In addition, many of the so-called corporate farms are really family enterprises incorporated for various economic and legal reasons.

The number of family farms selling over $100,000 increased by 254% from 1969 to 1974, while the number of corporate farms in this class increased only by 96%. At the other end of the economic class spectrum, however, family farms selling less than $5,000 decreased by only 23%, while corporate farms decreased 44%. These data also give support to our earlier assertion that price increases might have increased the number of "small" farms, and it is likely that these were predominantly family farms.

It is frequently alleged that it is the tax system which is primarily responsible for a shift in organization from individual proprietorships to limited partnerships and corporations. The tax system permits cost write-offs in agriculture against ordinary income inside and outside of agriculture, and taxes long-term capital gains at a lower effective rate than ordinary income. Estate law also was alleged to be an impediment to the successful transfer of family farms between generations. These factors may, indeed, be important; but their impact between 1969 and 1974 seems to be quite different than is commonly thought. Much of the sharp reductions in partnerships is probably attributable to the Tax Reform Act of 1969 (which, among other things, reduced the tax loss advantages to livestock and citrus farming) and to the 40% reduction in cattle prices during 1974. Further, throughout the period there was steady progress toward the enactment of the Tax Reform Act of 1976 which, for example, limits deductible farm losses from taxable income only up to the capital risked. It is generally held that these provisions will have widespread impact on the flow of nonfarm investment to agriculture—in particular, limited partnership syndications will no doubt continue to move to nonagricultural ventures with nonfarm real estate receiving primary interest.

Corporations are attractive for quite another set of reasons relating to payment of salaries and fringe benefits to corporate employees, limitation of personal liability, the procurement of capital, and estate transfer and planning. These advantages did not worsen 1969–74, and in fact, may have improved.

[4] Computed from *U.S. Census of Agriculture, 1959*, vol. 2, chap. 11, table 5; *1964*, vol. 2, chap. 8, table 25; *1969*, vol. 2, chap. 3, table 21; *1974*, printout of preliminary table 28, vol. 2.

[5] Computed from *U.S. Census of Agriculture, 1969*, vol. 2, chap. 3, part 2, table 11; and *1974*, printout of preliminary table 28, vol. 2.

Residency of Farm Operators

Almost continuously for at least twenty-five years, farm operators have tended to locate their residences off the farm in increasing proportions. The comparative percentages are 7.6 in 1959, 9.5 in 1964, 15.5 in 1969, and 18.8 in 1974.[6] The plains and western states lead the nation in off-farm residency. The reasons appear to be the high costs and inconvenience of isolated farm residence under highly extensive land use where communities cannot economically extend services and amenities into the hinterlands.

All types of farms, except general farms, had increases in the percentages of off-farm residences between 1969 and 1974, and only dairy (3.6%) and poultry (8.4%) were under 10% off-farm residency. Thirty-five percent of cotton and 30.0% of fruit-and-nut farm operators lived off the farm.[7] Residency data by economic class reveal the relatively high off-farm residence at both ends of the class spectrum, and every type of farm, except vegetable farms, displays this pattern.

Off-Farm Work

The census raises two questions about off-farm work: (*a*) does the farm operator work off the farm at all, and (*b*) if he does, how many days? The percentage of total commercial farm operators who reported off-farm work dropped unexpectedly from 43.3% in 1969 to 35.2% in 1974.[8]

The reduction in off-farm work reported was also applicable to every economic class, reversing a long-time trend. This reduction was quite large in the classes over $20,000 of sales, but only slight in classes under $20,000. Given the proclivity of farmers on the smaller farms to work off the farm, these results are expected.

The percentage of commercial farm operators reporting 200 days of off-farm work was 20.5 in 1974 as opposed to 20.8 in 1969, virtually no change. The percentage of operators working off the farm 200 days or more in classes over $40,000 of sales declined, but there was an increase in the percentage in the classes under $40,000 of sales. One possible explanation is the exceptional farm income years in 1973 and 1974, which may have allowed the larger farmers to give up their off-farm employment and still maintain a desired income level. Highly profitable farm production would also have created substitution effects favorable to on-farm work compared to off-farm work.

Farm Income

Farm family income from all sources has been closing in on average nonfarm family income since World War II and, in fact, barely exceeded it in 1973.

Because of highly fluctuating farm output prices, there was a good deal of instability from year to year in farm family income derived from farm sources. On the other hand, income accruing to farm families from nonfarm sources has increased slowly and steadily over the postwar period. With a substantial excess supply of farm products in prospect, a real possibility in the near future is that income from nonfarm sources might well again exceed that from farm sources as it did from 1967–1972, especially if off-farm work of farm operators returns to pre-1974 levels. A major uncertainty is the extent to which off-farm employment of farm wives and children will affect family income. It has been estimated that the proportion of the nonmetropolitan female population over fourteen years of age in the labor force increased from 30.3% in 1960 to 36.1% in 1970 (Hines, Brown, Zimmer).

These aggregate net income figures fail to reveal the variance in the profitability of agricultural production through the years (see table 5). From net income in agricultural production are subtracted imputed returns to operator, labor, management, and interest on farm debt; the remainder is residual earnings to equity in production assets. Even during the last five years there has been large variability in this residual.

Given that farmer equity in production assets continuously increases over the period (often at a high rate), the ratio of earnings to asset equity varies even more than the residual earnings. The 1973 rate of return to equity, 10.2%, is almost double that for any other year and is more than four times that for 1976. These low rates of return, except for 1973, suggest the continuing plight of agriculture. What other major sector of the economy

[6] Computed from *U.S. Census of Agriculture, 1969*, vol. 2, chap. 3, part 3, table 4; *1974*, printout of preliminary table 31, vol. 2.

[7] Computed from *U.S. Census of Agriculture, 1969*, vol. 2, chap. 8, table 22; *1974*, printout of preliminary table 32.

[8] Computed from *U.S. Census of Agriculture, 1969*, vol. 2, chap. 7, table 17; and *1974*, printout of preliminary table 31, vol. 2.

Table 5. Return to Equity in U.S. Farm Production Assets from Production Income, 1960, 1965, and 1970–76

Year	Net Income from Production	Imputed Returns to: Labor	Imputed Returns to: Management	Interest on Debt	Equity in Production: Residual Earnings of Assets	Equity in Production: Assets	Rate of Earnings to Asset Equity
	$ (million)						%
1960	16,195	9,502	1,748	1,339	3,606	140,836	2.6
1965	19,589	8,366	2,091	2,091	7,041	160,368	4.4
1970	22,899	9,813	2,713	3,365	7,008	209,551	3.3
1971	23,641	10,246	2,800	3,533	7,062	217,164	3.3
1972	29,384	10,444	3,258	3,879	11,803	235,290	5.0
1973	47,510	11,244	4,484	4,683	27,114	266,672	10.2
1974	41,272	12,695	4,649	5,745	18,183	332,689	5.5
1975	39,796	12,983	4,444	6,536	15,833	357,962	4.4
1976	36,129	14,185	4,753	7,334	9,857	409,466	2.4

Source: *Balance Sheet of the Farming Sector, 1977.* USDA ERS Agr. Info. Bull. no. 411, p. 24.

yields such a low return on equity capital on average? As tax advantages for nonfarm investors (via the 1976 Tax Reform Act) are reduced or eliminated, these low relative returns do not suggest great future interest in agriculture by outside investors.

Farm Debt

As is common knowledge, farm real estate debt has increased since 1955 (table 6, row 1). There is also some evidence (row 2) that the ratio of real estate debt to total farm debt has increased, although a leveling off has occurred since 1970.

More significant is whether or not the increases in farm real estate debt are justified, given the asset and income situation in agriculture. The value of real estate assets per farm increases over the period (row 3). The ratio of farm real estate debt to farm real estate assets increases until 1970, after which it declines (row 4). This ratio would suggest that heavy increases in real estate debt are being more than matched by increases in the assets purchased with that debt since 1970.

This point is even more obvious in the differences in the changes in assets and the changes in debt (row 5). These figures are positive, indicating that assets are increasing

Table 6. Various Measures of Farm Debt 1955, 1960, 1965, 1970, 1975, and 1977

	1955	1960	1965	1970	1975	1977
1. Farm real estate debt per farm (dollars)	1,772	3,049	5,630	9,879	16,484	20,504
2. Farm real estate debt per farm divided by total farm debt per farm multiplied by 100 (percent)	46.7	48.8	51.3	55.0	56.6	55.2
3. Real estate assets per farm (dollars)	21,963	34,610	49,911	73,085	334,853	180,661
4. Farm real estate debt per farm divided by farm real estate assets per farm (percent)	8.1	8.8	11.3	13.5	12.2	11.4
5. Change in assets minus change in debt (dollars)	[a]	11,370	12,720	18,925	55,163	41,788
6. Farm real estate debt per farm divided by family income from farm sources multiplied by 100 (percent)	—	95.6	138.9	178.7	159.3	[b]
7. Farm real estate debt per farm divided by total farm family income multiplied by 100 (percent)	—	57.9	73.6	84.7	79.7	[b]

Source: Computed from *Balance Sheet of the Farming Sector, 1977,* table 3; and *Agricultural Statistics, 1976,* table 644.
[a] Not applicable.
[b] Not available.

in value even faster than debt is increasing. These differences increase sharply until 1975, indicating the rate of change in asset appreciation is higher than the rate of change in debt. The number for 1977 is lower than for 1975, but is still high, indicating a large increase in net worth on the average farm.

All together, these data indicate that the increases in farm debt and, particularly, farm real estate debt, are being more than matched by increases in the value of farm assets. Of course, increases in net worth do not mean that farmers do not experience critical net income problems. In percentage terms, increases in debt since 1970 are not matched by increases in farm family income. If debt continues to rise at a faster rate than net income, a critical liquidity problem as well as a net income problem could soon arise.

Conclusions

The census numbers reveal that commercial farms are becoming fewer and larger and are becoming so at a decreasing rate. However, price rises and definitional changes have seriously distorted what is really happening to both farm numbers and farm size. We suspect that the larger farms are increasing in size at a slower rate than the economic class data in the census imply but at a faster rate than the census acreage data imply. Farm numbers undoubtedly have been enlarged by price inflation which has pulled many additional small farms under the census definition.

On the question of the impact of technical change and agricultural policy on farm size, we have uncovered no convincing evidence to indicate any change from historical trends. As for the ways in which farms are organized, recent evidence indicating the strength of the family farm is explained in the various taxation laws; and, if anything, we expect a continued decline in limited partnerships in agriculture. We see continuation of present trends in tenancy and residency. Over the next few years at least, we expect a rise in income from nonfarm sources relative to farm sources. Because of the strong possibility of declining land prices, the equity/debt relationship could be a substantial problem for many farm operators who have invested in land since 1972.

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Some Questions of Value and Scale in American Agriculture

Philip M. Raup

A most revealing characteristic of an economic system is the value it places on land. The modes by which that value is expressed and the methods of its reckoning are identity criteria of fundamental significance. In a market economy, the linkage between this value structure and the income flows that support it provide a trend indicator that is akin to body temperature in the human anatomy. Using this parallel, we must conclude that the American agricultural economy is feverish.

For the forty-eight contiguous states, agricultural land values tripled since 1967, with over 80% of that increase occurring since 1972. The increase has not been uniform among states, with the greatest increases centered in states of the Corn Belt, and in North Dakota, Montana, Pennsylvania, and West Virginia. The smallest increase occurred in California, and increases were below the national average in Arizona, New Mexico, the southern Great Plains and Mississippi Delta states, and all states of the Southeast except Georgia, South Carolina, and Virginia (U.S. Department of Agriculture 1977a, p. 22). In broad terms, cash-grain crop producers have benefited most from recent land value changes, while producers of cotton, fruits and vegetables, other specialty crops, and animal products have lagged behind.

Farm expansion buyers have been the dominant force in this recent upsurge of land values, accounting for 63% of all purchases for the year ending 31 March 1977. In Corn Belt counties (for example, in southwestern Minnesota) this figure approaches 80% (Christianson, Nelson, Raup, p. 19). With some exceptions in areas adjacent to large urban centers, these high farm land prices are not the result of an invasion of the farm land market by nonfarm buyers. The principal strength in the current land market is provided by farmer demand for tracts of land to add to their holdings.

This is a reflection of the financial capacity created for existing farmers by the windfall gains of land price inflation. If a farm is debt free or burdened with only a small mortgage, an established farmer can spread the cost of additional land over his entire acreage and bid this advantage into a higher price offer for any land that comes onto the market.

A recent study of Illinois farms shows that, if the farmgate price of corn is $2 per bushel, it would have required the income-producing capacity of approximately three acres to finance the purchase of one additional acre, at 1976 production costs and land prices (Scott). This provides a rough measure of the extent to which land prices have been inflated by the demand from farm expansion buyers. A farmer who is not in the top segment of farm income receivers, and who does not own a substantial acreage of debt-free land, is virtually priced out of the current land market.

The danger in this situation lies in the threat of land market instability. For two years we have experienced the phenomenon of falling farm product prices and rising land values. One interpretation of the current land market is that it exhibits many of the characteristics of an inflationary boom that is nearing its bursting point. To assess this possibility we need data that we do not have on the nature of the total demand structure for farm land.

The component of that structure for which we have the most copious data is the demand for the products of land. In a recent discussion, Gardner has suggested that "perhaps the demand curve facing American producers of farm commodities has become much more

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elastic as foreign demand has become more significant in recent years and many more substitutes are available for American produced commodities. If so, price fluctuations would have been reduced because of a given supply shift" (p. 189).

If Gardner is right, and the demand for American farm commodities has become more elastic, this should be reflected in the derived demand for farm land. It is difficult to interpret recent land market behavior as support for this conclusion.

It is much more plausible to argue that the derived demand for farm land has become less elastic with respect to price. Many of the most important foreign buyers of American farm commodities are in the market more or less independently of price. The Russian demand for American grain has been largely unaffected by price in several recent years. The stability of Japanese demand for grain and soybeans since 1972 suggests that it has been in spite of price, not because of it. This is also the most reasonable interpretation of Chinese demand for American grain.

The five largest recipients of U.S. wheat in 1976–77 were Japan, the USSR, India, the Republic of Korea, and Egypt, in that order. Among them they accounted for 49% of all U.S. wheat exports in that year (USDA 1977b, p. 17). It is improbable that price played an important role in their decisions to import.

Other more direct sources of increased demand for farm land also contribute to inelasticity rather than to elasticity. Hobby farmers are often insensitive to land prices, as are urban refugees seeking rural residences. Foreign buyers of U.S. farm land include a number who are driven by a push-force of fear of domestic instability rather than by the pull-force of cheap U.S. land. Tax-shelter demand for land is not unrelated to land prices, but there is little evidence that land buyers seeking tax shelters are very sensitive to land prices.

In short, it might be argued that the demand for farm land has become more inelastic with respect to price in recent years. This would be consistent with sharply increasing land prices in the face of falling farm commodity prices, but it leaves us with a key question: Is this a transitional phenomenon, characteristic of the up side of a land market boom that is approaching its peak? Or, is it a more durable phenomenon, reflecting a genuine shift in the demand curve for farm land?

An answer to this question must begin with recognition of the fact that a greatly increased world demand for American grain and soybeans has created an inflationary psychology, but this is not the only explanatory factor. A variety of institutional arrangements combine to give added purchasing power to prospective land buyers in high income brackets. These include (*a*) the privilege of using cash-basis accounting; (*b*) preferential taxation of any prospective capital gains; (*c*) deductibility of interest on borrowed funds as a business expense, in computing income tax liability; (*d*) investment tax credit; and (*e*) several methods of computing accelerated depreciation.

In combination, these institutional features give a pronounced advantage to a farm land buyer who is in a relatively high income tax-bracket, has substantial debt-carrying capacity, is highly mechanized in the production of cash grain crops, and can make optimum use of the investment tax credit and accelerated depreciation. For example, a farmer with a combined federal and state marginal income tax rate of 33% (not uncommon in cash grain areas) and using a seven-year depreciation schedule can obtain a present-valued tax saving over the seven years equivalent to approximately 40% of the cost of a new item of equipment. If his marginal tax rate is 10%, the tax saving is only 18%. If he has no net taxable income, he must pay the full price for the equipment item (Fuller, p. 3). It is not surprising that the greatest increases in farm land prices in the past five years can be traced to farm expansion buyers in cash-grain-producing areas. Our institutional structure has reinforced the impact of sharply rising grain prices, following the sudden increase in world demand after 1972.

Any guarantee of farm commodity prices also exerts a differential impact on farms in different size classes. To the extent that a risk of price collapse is reduced, investment in the production of that commodity is made more attractive to large-scale producers. This creates a dilemma in farm price-support policy. If the price is set high enough to cover the costs of high-cost, small-scale producers it produces windfall gains for large-scale producers, enabling them to buy out their small-scale competitors. Alternatively, it enables them to bid up the price of land to levels that discourage the sons of smaller, family-type farmers from seeking careers in farming.

One of the greatest advantages of the single-proprietor or family-type farm has been

its capacity to absorb risk. If risk is too great, the farm will fail. But if risk is reduced it increases the attractiveness of land ownership to nonfarm investors, whose capital position enables them to take advantage of the institutional features of our tax and credit policies outlined above.

The possibility of a take-over of large segments of American agriculture by nonfarm capital is real; but on present evidence the current threat to smaller family type farms is not from outside investors or nonfarm capital, it is from the larger neighboring farms in the same community.

Conflicting economic forces and public policies have created this threat of economic cannibalism within agriculture, in which the strong consume the weak. We have credit policies that cheapen the cost of credit for larger borrowers. We have tax policies that encourage vertical integration, agglomeration, and farm size enlargement. We tax unearned income in the form of capital gains more leniently than we tax earned income. We use investment tax credits and accelerated depreciation to hasten the substitution of machines for labor, with the result that these policies are of greatest advantage to those sectors of the economy that are already most highly mechanized. We adopt farm commodity price support programs that are flat-rate supplements to price, and thus yield benefits that are a linear function of output. If there are any economies of size available through farm size enlargement, this system gives a differentially larger reward to the larger firm. These policies are not scale-neutral. Taken together, they create incentives for farm land buyers to shift attention from efficiency and productivity criteria to a search for rewards in the form of farm expansion, agglomeration, and land value appreciation.

In the past, much of the discussion of farm problems has assumed that the distortions of policy outlined above have been of principal value to nonfarm investors, large conglomerate corporations, or extremely wealthy individuals. A phenomenon of the past five years has been the emergence of a segment of farmers whose income levels, scale of business, and income tax obligations make them effective users of price, credit, and tax policies that formerly were of primary benefit to nonfarmers.

It is ironic that when efforts have been made to shift to accrual accounting, reduce the preferential taxation of capital gains, limit the deductibility of interest on borrowed funds, remove the inequities of accelerated depreciation, repeal the investment tax credit, or put a ceiling on government farm price support payments, family-type farmers have usually opposed any of these reforms. Policies that contribute to the decline of small or family-type farms, in short, have been supported in most cases by family farmers.

Why is this a problem? If small scale or family-type farmers persistently support policies that contribute to their downfall, why should this invoke a public interest? Time and space limitations prevent any detailed exploration of this issue, but the broad outlines of an answer can be indicated by a focus on two dimensions: the contribution of intermediate-scale farms to innovation and change processes, and the carrying costs of capital in farms of varying scale.

At the lowest level of farm size, innovation becomes an impossibility because risks of failure threaten family subsistence. The scale at which this applies varies tremendously, from perhaps one acre in Java to a square mile in the United States wheat belt. As we ascend the size-of-farm scale, the opportunities for experimentation increase and the price of failure declines. At some point relatively low on the size scale, there is an optimum range in the ability of an individual or a firm to capture the rewards of successful innovation without incurring unacceptably high risk. At smaller scale, the risk is too great. At larger scale, the ability to retain the rewards of innovation must be shared with others, and the time required to secure agreement to changes in traditional modes of technological behavior becomes excessive. Medium-scale, family-size farms in the United States present an outstanding example of this principle, and consumers have been the major beneficiaries. Competition among farms has insured the rapid diffusion of technological change, and no farm or combination of farms has been able to restrict supply, control price, or retain an unwarranted share of the benefits.

The failures that have occurred in this sifting and winnowing process have been frequent, but they have also been small scale. While often high cost to the individuals concerned, they have been low in social cost to the total economy. Change has been spread over time, and technological unemployment has been accommodated through generational

shifts rather than through layoffs and firings. This is the basis for the conclusion that a major strength of the family-size farm is that it can fail at low social cost.

The significance of this conclusion can be measured by contrasting the impact of technological change in corn and cotton production. Although there were and are large-scale corn farms, single-proprietor, family-type farms predominated in corn production during the period of rapid introduction of hybrid corn, and mechanization. This was accomplished without the destruction of rural communities and without dumping large masses of displaced labor into urban-industrial job markets. A much larger fraction of cotton production has historically been produced on large-scale units operated with sharecropping labor. Displacement of this labor through mechanization and the migration of cotton production from the South to the high plains of Texas and the irrigated lands of the Southwest has disorganized the rural communities from which cotton departed and created a burdensome social cost for the cities to which displaced cotton workers fled.

The lesson from American experience is clear. Large-scale farms resist change, but when it comes, it comes with a rush and at high social cost. The society has a direct interest in supporting a mix of farm sizes that will minimize these costs.

A second measure of the public interest in the structure of farm sizes is provided by the cost of capital. If we abstract from highly space-intensive livestock, dairy and poultry production, and fruit, nut, and vegetable crops, the cost of land remains the major item of capital investment in American agriculture. And its fraction of total asset value has been increasing. In current dollars, farm land and buildings accounted for 63% of the total value of assets in American agriculture in 1940, 57% in 1950, 64% in 1960, 68% in 1970, and an estimated 75% at the end of 1977 (Melichar and Sayre, p. 37). In 1973 (the most recent year for which national estimates are available and before the big increase in farm land values), the value of farm land in current dollars was an estimated 254 billion compared to a total value of all land used in manufacturing and nonfarm nonmanufacturing businesses of 206 billion (Kendrick, p. 77). Since 1973 the value of farm real estate has doubled, and its fraction of the total value of all business capital in land has increased sharply. Farm land ownership has provided the greatest opportunity to benefit from appreciation in asset values in an inflationary period.

Who will supply this expensive land capital to the farming sector? The conventional wisdom is that large-scale units are needed to attract and hold capital in farming. As the fraction of land to total farm capital increases, this argument has seemed to gain momentum. But the assumptions on which it rests deserve a closer look.

Large-scale business firms must receive a rate of return on land capital equivalent to their opportunity cost of capital. If they do not, they find it exceedingly burdensome to immobilize large capital sums in illiquid investments in land. To cover costs of production, large corporate or noncorporate farm businesses must include the full opportunity cost of land capital in their profit calculations.

The situation is sharply different with single-proprietor, family-type farms. With full economic rationality, they can include in their calculation of rate of return a variety of nonmonetary rewards, including pride of ownership, continuity of family, freedom of choice of work time and pace, and ability to identify effort with reward. As Thurow has emphasized, the desire to own assets is not adequately explained by the flows of money income they generate (Thurow, pp. 141–42). Power, authority, freedom, a purpose in life—these are pervasive motive forces, and the role of public policy is to harness them for the public good.

This has been achieved, although imperfectly, in proprietary types of businesses and especially in family-type farms. Their owners will hold the large sums of land capital required at nominal rates of return that no large-scale business can tolerate. This is not an error in calculation, nor is it evidence of an imperfection in the market for land. It is rather a reflection of the fact that prospective owner-operators of farm land have opportunities to value dimensions of intangible wealth that are denied workers in nonproprietary businesses. They can do this in their bid-prices for land.

This is a part of the explanation for the recent rapid run-up in farm land values. Those aspects of intangible wealth that can be acquired with the purchase of land have appreciated in relative value as they have become scarce in the nonfarm world. Pride, status, and a sense of self-worth have been bid

into the price of farm land. These same motives lead small-scale, family-type farmers to hold capital in land at low social cost. In the short run, mobilization of capital for farming may be more easily achieved by large-scale, nonproprietary, or corporate, units. In the long run, the costs of this capital will have to be covered by the price of food, or the capital will be withdrawn. Family-type farmers will hold land capital at lower cost and without forcing the full costs of carrying this capital into the national food bill.

A population of viable family-type farms is thus not only more efficient in promoting innovation and adaptation to technological change, it will also carry the required capital stock at lower rates of return. The public interest in preserving this structure should be apparent. If it is not effective, we then have two alternative policy options. We can subsidize nonfarm investors in order to persuade them to carry farm land capital, or the public can own the land.

We have gone a long way in the direction of subsidizing farm capital investment by the nonfarm sector. The aspects of credit and tax policy outlined in the early paragraphs of this paper are an attempt to equip nonowner-operators with bid power in the farm land market that will offset at least in part the advantages that prospective owner-operators can gain from their ability to include intangible values in their bid prices. This has not been the result of any conscious public policy. It arises instead from the insistent desire of farm and nonfarm investors to acquire a share of recent capital gains in land. The culprit in this scenario is inflation. In a narrow sense of asset value appreciation, no sector of the American economy has benefited more from inflation than land owners in the grain belts, where family farming has been the predominant type. In a longer run perspective, it is difficult to identify any sector of the economy that has more compelling reasons to bring inflation under control. In the past decade, farm land values have tripled, there has been virtually no appreciation in the capital value of common stocks, and we have witnessed a phenomenal growth in the demand for tax shelters in farming and real estate. This has been one of the devices by which nonfarm capital has sought some measure of bidding equality with farm owner-operators in the farm land market. It is both a consequence and a cause of land price inflation.

If this policy choice is expanded, it promises to generate a form of tax-shelter socialism for the rich. Since the burden of these preferential tax policies must be borne by other taxpayers, the cost of this method of attracting capital to agriculture does enter the monetized sector. Instead of appearing in the food bill, the costs of subsidies to nonfarm investors appear in the form of an altered incidence of taxation and a distorted pattern of income distribution. The monetary costs can be calculated, but they are almost certainly not as important as the political and social costs of the distortions and inequities resulting from this method of providing capital to agriculture.

If we persist in these policies they will drive the full-time, family-type farmer out of farming. The agricultural structure that will emerge will consist of a small number of large to very large units that can take maximum advantage of credit, tax, and price support policies, and a large number of small or part-time farms whose owners will reckon their return on capital in terms of amenity values rather than monetary rewards.

We will have an opportunity to test the validity of this observation in the course of the current debate over land costs and farm price-support levels. In the final analysis, this is really a debate over the desired level of land values. Farm commodity prices must go up, or land values must come down. As painful as it may prove to be, it is virtually certain that family-type farms have more to gain from a downward adjustment in land values than from an upward adjustment in commodity prices. The risk-bearing capacity of the family-type farm is its greatest comparative advantage. To the extent that risk is reduced, the balance will be tipped toward an agricultural structure dominated by large-scale, highly capitalized enterprises. The goal of agricultural policy is to discover a middle ground, in which appropriate scales of farm size and technology are relatively free from threats of destruction by either their enemies or their friends.

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Some Nonfarm Effects of Changes in Agricultural Technology

Paul W. Barkley

In 1877, Thomas Alva Edison developed a crude recording device that was to become the phonograph. Although Edison soon abandoned the phonograph in order to perfect the incandescent light, he eventually returned to the possibility of reproducing sound. By 1920, the phonograph was available for public purchase and many homes proudly displayed the machine that could reproduce sound on command. The phonograph was a new technology. Once perfected, it brought good music to any home able to afford the device and the records to go with it. Once a single record was obtained, the contents of the record could be heard as frequently as its owner desired. Because only the better artists were recorded, the phonograph's music was better and it could be heard oftener than the music provided by the fire department band, the itinerant musician, or the traveling symphony orchestra.

While bringing music and a form of culture to millions of individual homes, the phonograph brought unbelievable changes to the music-producing industries. A live performance—even in 1920—was filled with mistakes. The proficiency of the artist was gauged by his ability to recover from errors. The phonograph changed that; no mistakes were allowed. But the mistake-free performance was not confined to the recording studio. Once accustomed to mistake-free records, the sophisticated listener demanded that live concerts be mistake free too. A change in technology brought changes in the medium, the groups that produced music, and the listeners. An apparently ubiquitous good brought havoc to all involved in the production, distribution, and consumption of music. The unanticipated effects of the new technology changed input mixes, income distributions, and consumer demands. Most important, there is no going back. Concert artists will never again be applauded for their capacity to recover from a lapse in memory or a misplayed note.

Many points can be made by comparing technological development in agriculture to the development and improvement of the phonograph. While production and consumption activities in music and food are not necessarily determined by the same factors, there are some similarities in the response to technological change. These similarities will serve as points of departure for arguments generated in this paper. The discussion will begin with reference to some definitions and the difficult nomenclature of the day.

Some Definitions

Technical experts, agricultural economists, citizens, and advocates have entered a period of disquiet over the environment, the apparent scarcity of energy, population distribution, the quality of agricultural products, the use of chemicals, the structure of agriculture, and the use it makes of steadily improving technologies. It is not yet clear whether agriculture is to be a mere whipping boy or a legitimate object of concern for those who wish to ameliorate these ills.

The groups that focus attention on real or imagined inappropriate uses of agricultural technology often suggest that the industry could redress many intraindustry and societal ills by adopting some combination of intermediate or "appropriate" technology, organic farming, or by adopting the position that small is beautiful. There is great confusion in these recommendations because they do not necessarily relate to the same things.[1]

Technology is high technology when all ef-

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[1] The late E. F. Schumacher is responsible for much of the interest surrounding today's interest in intermediate and appropriate technology.

fective opportunities to substitute capital for labor have been utilized. Low and intermediate technologies are present only in situations in which additional substitutions of capital for labor are known and possible but are not followed. A monastic order may follow low or intermediate technology (Johnson, Stoltzfus, Craumer). The Bantu tribe of Africa, for example, follows what for it is high technology—the Bantu have made capital-labor substitutions within the context of their own society. Regardless of context, a switch to intermediate technology requires the sacrifice of some opportunities. In U.S. agriculture, the switch to intermediate technology may reduce the optimum scale of operation and reduce the knowledge and skill requirements that attend farming. It may also increase the average cost per unit of output, and it may require the farm operator to learn to live on lower net farm income. This switch to intermediate technology is not anti-American or even un-American, but it is certainly contrary to the historical pattern of development in U.S. agriculture.

Intermediate technology is often confused with organic farming. While it is true that organic farming may require different technologies than those used by conventional farmers in the Corn Belt or High Plains, organic farming can be carried out—perhaps it is best carried out—using high technology. Organic farming is the practice of using only natural inputs to produce agricultural products. This, of course, leads to heated discussions of what is natural and what is not, but the message is clear that organic farming calls for a reduction in the use of chemical fertilizers, pesticides, and herbicides. It calls for using natural manure, green manure, crop rotations, and the small-scale biological warfare such as that in which lady bug beetles are used to devour aphids (Aldrich).

There are several problems associated with organic farming. It can be either product- or process-oriented. If it is product-oriented, the organic farmer may be using a very high technology to produce a high quality product that can be sold at premium prices in health food stores. If it is process-oriented, the organic farmers may have an almost religious zeal regarding the way food should be grown. These two approaches to organic farming should not be confused. The definition of scarcity and efficiency may be quite different for the two approaches and this difference is sufficient to warrant different economic analyses of farms operating under each of the two objective functions.

Agriculture and Technology

The United States has always been impressed with progress, growth, and development. Although these terms are ambiguous, those who talk of them will almost certainly agree that however these things are defined, they require intensification of technology through capitalization and mechanization. In agriculture, capital and mechanical progress generally have been made available from outside. The agricultural industry is competitive, and it is assumed that no one farmer can produce a sufficiently large proportion of a crop to have any effect on price. This makes for tidy analysis, but it has an insidious consequence: no one farmer can earn profits large enough for him to engage in research and development to find new ways of performing old tasks. Even if he did, the new methods would be copied quickly and the expanded supply would lower prices, dissipate rents, and dampen any incentive to further invention or adoption. Observers outside the agricultural industry have noted that several aspects of agricultural production offer significant opportunities for individual entrepreneurs to capture economies of scale. If these economies are to be captured, however, someone outside of production agriculture must invest the time and effort to innovate and teach the process of adoption and adaptation. Although many private firms have developed economy-generating agricultural technologies, the public has been the major single sponsor for developing and promoting such technologies. Public research agencies have been responsible for developing hybrid corn and the mechanical harvester for tomatoes, and for teaching the use of chemical fertilizers. Just as Thomas Edison developed the phonograph and imposed a higher standard of excellence on performing artists, the public has imposed and continues to impose higher and more revolutionary technologies on agriculture (Rasmussen).

The consequences of this massive infusion of technology have been widespread and it is not known whether, on balance, these consequences have been good or bad. Agricultural output has increased, but it has become concentrated in areas away from markets. The

concentration of production in remote areas has required the picking of crops that have not yet ripened, their storage, and increased shipping costs. This also sometimes has lowered the quality of final products and has aroused the ire of consumers. The extent of consumer dissatisfaction has never been measured, but it is certain that the technologies designed to capture economies of scale have taken their toll.

Most of us are content to accept the position that we are trapped by the state of available technology. General Motors is trapped by its present technology, but it has the essential element of profit that enables it to conduct additional researches that, in turn, yield economies of scale in at least some portion of its activities. True, Chrysler and Ford may imitate, but profits continue to accrue to General Motors and the distribution of profits is decided by a corporate board which examines the forces of supply and demand and makes conscious decisions about product prices, continued research and development, and rate of technological progress. General Motors is trapped by technology but the trap is fitted with a loose spring. Its context allows GM some latitude.

In agriculture, the situation is quite different. The individual firm, even the large-scale corporate farm, takes prices in both the factor and product markets. It operates near the low point on its average cost curve and earns profits that are close to the opportunity cost of capital. If additional profits accrue to the firm, they are capitalized into the value of the firm's fixed resources and they encourage expansion and entry into the industry. The only way the individual farmer can appropriate the gains of new technology is by being first to adopt a cost-reducing technology or by selling out and taking the gain in the form of increased capital values. The farm operator is thus trapped by technology. But the problem is much more severe: he is trapped by a technology that is designed by someone else and made available to all farmers at zero cost.

Those off-farm designers of tomorrow's agricultural technology are not evil men. They are well-meaning investors, tinkerers, entrepreneurs, and scientists who are following the dictates of the growth imperative: substitute capital for labor, for, in so doing, output can be expanded and a greater agricultural product will be available for the nonfarm population. Society captures the benefits of economies of scale in agriculture, and the farmer remains on the technological treadmill.

Nonfarm Effects of Technological Change

Changes in product quality and problems in the rural nonfarm sector are possible consequences of radical changes in farm technology. Both are effects imposed by technology and thus fit within the scope of this discussion. Both problems need considerable elaboration, but they need to be treated in separate ways.

Product quality has been an agricultural problem for many decades, especially in the 1930s and 1940s when oleomargerine was replacing butter as a table spread. Oleomargerine was "not authentic," even though it was produced from agricultural products and carried the potential of widening the market for some forms of agricultural commodities—butter enjoyed the advantage of being identifiable as a home-grown product. But the problem goes beyond butter and margerine. Products grown by capital-intensive factory-farms taste different and look different from those that are carefully nurtured in the family garden. Some who advocate a return to small farming, organic farming, or the use of intermediate technology hope that the switch will bring back the tasty, high quality product of yesteryear (Environmental Action Bulletin). Such may be the case, but this view ignores the role of the processor. The processor needs uniform color, uniform size, and tough skins. Unless these can be produced by intermediate technology and smallness, the agricultural processing sector will continue to press for a technology that does produce them and the farmer will be trapped further by someone else's technology.

There is, however, recourse to the problem of food quality. Consumer sovereignty is an economic concept, and even though there are limits to the measurement and usefulness of the concept, consumers are sovereign. The problem arises in connection with the limits over which consumers choose to exercise this sovereignty. They will not exercise it until the perceived benefits of doing so are greater than the anticipated costs of an alternative path of action. Farm operators are forced by technology to produce a tough-skinned, tasteless tomato that is picked green then subjected to all manner of abuse before being dumped into the supermarket bin. The consumer is forced by technology, habit, and knowledge by buy this

fruit. If the product eventually becomes bad enough, the consumer will rebel and refuse to buy—he will exercise his sovereignty—and the agricultural industry will have to break out of its technology-imposed trap and produce an improved product. The market may require a new product and a new production method, but there is no a priori reason to believe that the switch in products will lower the intensity of the industry's reliance on technology.

A far more serious problem arises in connection with rural communities. For generations, improved substitutions of capital for labor have led to increasing farm size. This, in turn, has depopulated rural areas and brought overcapacity to rural communities. The farm operator is trapped by technological developments that are not of his own making, but he has some choices. He can sacrifice profit and continue to operate his farm using an intermediate technology.

The rural business, the church, and the municipal water system are not so fortunate. They also are trapped by agricultural technology because they are affected by rural population. Unlike the farm operator, they have no reasonable means of fighting back and adjustment to their present situations can be made only within narrow and carefully circumscribed limits. Thousands of towns are without sufficient clienteles to maintain viable business communities. Tiebout had a simple answer when he said that businessmen should vote with their feet, move out of the small town, and reinvest in business activity in larger, more viable communities. Unfortunately, Tiebout's answer ignores the fact that most retail businessmen have excess capacity in their stores. The haberdasher in a small Iowa town cannot follow his former customers to Des Moines, Dubuque, or Minneapolis, because these cities already have an adequate array of retail merchants and because he is ill-equipped to deal with the demands of a large town clientele. The rapid change in farm technology and the lack of commensurate changes in rural nonfarm technology has left a class of petty capitalists with nothing to do and no place to go.

The demise of the small town has brought a still uncounted waste of public and private capital. We do not know how many schoolrooms are empty, how many restaurants are closed, and how many auto repair businesses in rural areas operate at 10% of capacity. These widespread reductions in the utilization of capital have serious consequences on the distribution of both income and wealth in rural communities. They are a direct result of the death-grip struggle of farmers to adopt the latest technology, temporarily lower the average cost of production, and buy out their rivals. The farmer is trapped; the townsman is equally trapped but with an added disadvantage—he is forced to be a neutral bystander in the struggle. His only hope is that the community will last until the Keogh plan can take over!

Backing Down on Technology

The above observations are just that. Most agricultural economists have thought of at least some of these problems. What happens, though, when those who stress the use of intermediate technologies have their say? What effect will the choosing of intermediate technologies have on the agricultural industry and the industries that serve it? This is not an easy question. It will be addressed in parts related to labor and the population, energy, and rural America.

Labor and the population. One of the reasons for choosing a less intensive method of farming is to relieve agriculture's dependence on capital by substituting labor for nonlabor farm inputs. This switch in factor proportions offers a slower paced agriculture, increased opportunity to farm, and less nonfarm capital. The result of the switch would be lowered land/labor and capital/labor ratios. This, in turn, would lead to more farms, and perhaps an increased market demand for land to be used for the traditional, labor-intensive single family farm. This kind of technological transference is apparently the kind of change that many advocates of lowered technology have in mind. It is a romantic appeal that fits with the American myth of agrarian fundamentalism; it has contemporary appeal because it offers the opportunity to substitute labor (a flow resource) for capital (a stock resource).

There is, however, another possibility. A labor-intensive agriculture could be developed by making massive changes in the type of farming conducted in a general area. The Corn Belt could be used to grow hay and the Great Plains could be used to graze cattle. Capital/labor ratios would fall as would capital/output ratios, but land/labor ratios could actually rise, yielding agricultural areas that are more sparsely populated than at present. Such a

move would exacerbate the problem of community capital redundancy in rural areas. Thus, introducing an intermediate technology has indeterminate effects. It could solve rural problems or it could make them worse. While research is making inroads into the possibility of substituting stock resources for flow resources, the problem of sparse settlement remains largely untouched and this, from society's view at least, is the more important. If changing the technological requirements of agriculture becomes a widespread phenomenon, society should know what will happen to labor and population as well as the value and utilization of people-related capital such as schools, churches, and roads.

Energy. Energy has an intense interface with agriculture. The production of commercial fertilizer is a highly energy-intensive process. The mobile forms of capital used in planting, cultivation, and harvest are also high consumers, as is the whole network of agricultural processing facilities currently used to make agricultural output fit with the market demands of the contemporary homemaker. These obvious forms of energy use have been the object of a number of contemporary studies, but the studies themselves are inconclusive. The reduction in pesticide use must be offset by increased cultivation so energy gains in one area are offset by energy losses in another. Technical coefficients are not yet available to show the "energy best" way to produce agricultural products. Similar difficulties seem to plague those who have tried to develop energy budgets for organic farming as opposed to conventional farming. Some are beginning to note that more energy can be saved in the farmhouse than on the farm itself. Switching to Coleman lanterns and wood stoves does more to aid the energy crisis than switching from commercial fertilizer to organic manures or switching from herbicides to multiple cultivations (Johnson, Stoltzfus, Craumer, p. 376).

The relationship between agriculture and energy use is considerably deeper than the relationships between heating the farmhouse, the use of herbicides, and the frequency of cultivation. If U.S. agriculture adopts an intermediate mode of technology, a whole new set of capital fixtures and machines may be needed to carry out the needed farm operations. Although low technology equipment is known and available on a limited basis in the agricultural sector, its geographic distribution is not known and no market information system is in place to allow redistribution of this embodied capital to those areas where it can be used. Establishing the information system will require energy resources. If new intermediate technology equipment is needed, factories in the nonfarm sector will need to be retooled, labor forces trained, and market outlets developed. Although intermediate technology may be energy saving in agricultural production activities, it is not clear that the transformation would, on balance, save energy, stock resources, or time for the national economy. Those advocates of lower technology are indulging themselves in the luxury of self-deceit unless these massive energy and resource uses are counted in their budgets.

Intermediate technology and the rural community. The place of the rural community in a world of intermediate agricultural technology is neither well defined nor widely discussed. It would be comforting to suggest that the return to an intermediate technology would yield more traditional family farms while using a minimum of inputs from the nonfarm sectors. This cannot be suggested as either a normative prescription of how agriculture should look or as a positive statement of how it will look under intermediate technology.

The widespread adoption of intermediate technology may bring more people into a rural area. If it does, it may bring rebirth to many faltering towns. The result is not certain, however. If people return to the farm, will they settle for an intermediate technology town or will they want the high technology in nonfarm enterprises that can only be provided by towns of 200,000 or more? It seems quite possible that the farmer who chooses to toil as his father did may choose to take his leisure in a new and different setting. If this occurs, the local community may change its face, but it may not be the complete community that provides cohesiveness and continuity to its residents. It will be a retail center catering to the needs of a sophisticated clientele, but it will be imprisoned by the technology and the tastes of the farmers around it. Although it may be impossible to research the new technology's towns, it seems important that economists and policymakers begin to learn of the demands, needs, and desires of the farmers who might people these towns. Only by doing this can the resource requirements and energy require-

ments of the new rural community be understood. Again, resource savings in a low technology agriculture may be offset by resource costs in the nonfarm sector.

The most serious problems of rural communities will come in the public service sectors. Will a general change in the intensity of agricultural technology bring more or fewer children into rural schools? Will such a change require more telephones, gas lines, sewage systems, or police protection? These are important questions because each of these public services requires resources and it is not clear whether, on balance, an intermediate technology in agriculture will bring lower or higher requirements for resource commitments in rural communities. The problem is compounded by two other unique characteristics. First, public capital used to intensify a local infrastructure is expensive and once that capital is in place, it has zero or near-zero opportunity cost. Second, resources committed to the public sector must be allocated using nonmarket rules. We, as a society, have not been particularly effective in designing means of circumventing or supplementing the market.

A change in the intensity of use of agricultural technology will surely bring changes to the small towns that serve U.S. agriculture. It is certain that small towns will err in allocating funds in both their public and private sectors. In spite of the vast improvement in knowledge relating to rural communities, it is not clear that a new generation of low technology service communities would devote too many or too few resources to the provision of goods and services. Resolving this problem must surely be the largest research issue on the to-do list of those interested in retreating to lower levels of on-farm technology.

Discussion

So where does all this lead? There is growing interest in the adoption of intermediate technology in the agricultural industry. Some see this as a salvation from an impersonal, technologically oriented world that drives farm size to intolerable limits and prevents one man from ever being able to organize agricultural production. Others—the romantics—feel that the air-conditioned cab of a tractor pulling a hundred-foot wide harrow removes the art from farming and impersonalizes it, too. A third group argues that the modern reliance on chemicals and nonorganic substances poisons the final product making it mildly toxic for those who wish to consume it. A fourth group argues that the only way the world population can maintain itself is through the adoption of low technology, energy-saving, and labor-intensive methods of farm production. The usual response made by these groups is to damn technology and suggest that the interminable rush to increase yields and/or decrease costs has caused individual farmers to do things that are unwise, especially when they are accounted at the societal level.

This may all be true, but it still appears that we are and always shall be prisoners of what we know. Now, in the late 1970s, we have some choices. We can choose to adopt a mode of production that is less than the highest our technology allows. If we do adopt an intermediate mode, there will be rearrangements in the capital structure and income distribution in agriculture and in the rural nonfarm sectors of the economy.

So long as agriculture is organized in a fashion that closely resembles competition, one or a few producers can behave in a nonnormative fashion and get by without deleterious repercussions. Economic society is large enough to be able to indulge the fancies of a few persons who, for whatever reason, wish to backtrack and substitute labor for capital. To expect the entire agricultural industry to behave in this way is nonsense. Agriculture exists in a context. So long as that context is not severely altered, some can adopt intermediate or low technology, but adoption of low technology by all would change the context of agriculture and send repercussions through production agriculture, the nonfarm agricultural service sectors, and eventually, the entire economy. Not a great deal is known about either the direction or magnitude of these effects and as long as this uncertainty exists, it seems advantageous to encourage a mild venture into intermediate technology on a now-and-again basis. It seems untoward to make intermediate technology a part of agricultural policy or part of the recommendations elucidated and advocated by those who train and advise farmers.

Thomas Alva Edison revolutionized music by making sound reproducible on command. He was working for the public good and early

followers of Edison saw the reproduction of sound as a tremendous benefit to society. Little did Edison and his followers know that while making a new industry flourish, his technology trapped the original producers of sound and put unimaginable demands on them regarding the perfection of their artistry. For them there is no going back. It appears that agricultural technology is much the same. As much as one would like to be a part of the bucolic, slow-paced world of (say) the 1920s, the technology of agriculture and the economic context within which that technology is utilized prevents a return to an intermediate or lower form of combining agricultural land, capital, and management. Agriculture is, for the time being, trapped by its own technology.

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Discussion

Jerry A. Moles

It is most difficult to critique the work of another discipline, especially when the audience of that critique will be members of that discipline. Consequently, I had to search for a framework to guide me and found insight from an unexpected source. Sissy Hankshaw, the main character in Tom Robbins' *Even Cowgirls Get the Blues*, made several comments concerning the nature of social organization within the United States which seem relevant to this discussion.

> Disorder is inherent in stability. Civilized man doesn't understand stability. He's confused it with rigidity. Our political and economic and social leaders drool about stability constantly. It's their favorite word, next to "power." 'Gotta stabilize the political situation in Southeast Asia, gotta stabilize oil production and consumption, gotta stabilize student opposition to the government' and so forth. Stabilization to them means order, uniformity, control. And that's a half-witted and potentially genocidal misconception. No matter how thoroughly they control a system, disorder invariably leaks into it. Then the managers panic, rush to plug the leak and endeavor to tighten the controls. . . . And the blind pity is, rigidity isn't the same as stability at all. True stability results when presumed order and presumed disorder are balanced. A truly stable system expects the unexpected, is prepared to be disrupted, waits to be transformed. . . . Likewise, a stable culture, government or institution has built into it its own demise. It is open to change, open even to being overthrown. It is open period. Gracefully open. That's stability. That's alive (p. 238).

Sissy Hankshaw has mentioned three concepts which are important. First, the concepts of stability and its semantic opposition, instability, were discussed at this meeting in a number of ways. To some degree, all of the authors were concerned with the stability of U.S. agriculture. Second, while not mentioned specifically, the concept of power and its semantic opposition, powerlessness, were implicit in several contexts. Some individuals and organizations in agriculture simply have more power than do others and this warrants consideration. Third, the concept of system was not specifically mentioned, but if I understand Barkley's use of the concept "context," I believe he is referring to what I would call a systemic approach. It is becoming increasingly evident that one must explore the social, economic, and cultural contexts in the study of any single type of social structure. My own discipline, anthropology, has gone so far as to court the economists in search of assistance (Epstein). In truth, a systemic approach is impossible. There are too many variables to consider and too many valid conceptual frameworks available which can confound research findings. Nonetheless, the fact of an impossible task has failed to deter social scientists in the past. At a minimum, we can sympathize together concerning our difficult tasks and, with luck, perhaps generate a bit of insight beyond mutual commiseration.

Barkley has shouldered an impossible burden, that of exploring the nonfarm effects of changes in agricultural technology. Remarkably, he does a nice job in presenting several of the relevant issues. He is correct that changes in technology cannot be blamed for the world's ills. He clarifies some of the "looseness" related to the concepts of intermediate technology and organic farming. He is on target in stressing the importance of progress, growth, and development as broadly accepted societal values within our culture. These values are a part of the context in which agriculture exists. This is reminiscent of Jules Henry's (pp. 45–99) discussion of the influence of pecuniary philosophy in American culture. This produces "pecuniary truth" in which that which is true is that which sells, that which you want people to believe, and that which is not legally false. The philosophy has led to a pecuniary psychology, pecuniary history, even a pecuniary biology which deals with "product evolution" and, in the end, produces a pecuniary conception of the human animal with which we can judge the individual worth of our fellows based upon their income-

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producing abilities and their public display of symbols of wealth. Such a philosophy has led to what Wagner (p. 62) has termed a "backwards" technology. Instead of solving problems and meeting needs as expressed by a segment of the population, an attempt is made to create, through definition, a problem or "need." Next, efforts are made to "educate" people so that they will accept this definition, and, finally, a solution to the problem is marketed. In short, you develop the product prior to developing the "need." Such practices occur in food marketing. Cooney (p. 1) suggested that "by the time the year is out, food marketing specialists will have designed, packaged, tested—and sometimes discarded—dozens of new edibles you never knew you were going to want." It would be interesting to know how many of the food products in the supermarkets were responses to consumer demand and how many were creations of the advertisers. Food marketeers did not spend in excess of $4 billion in advertising over the past year for nothing (Cooney). Furthermore, Barkley is on target when he suggests that farmers have little control over the technology which is developed for their use and keeps them on the "treadmill." Again, it would be interesting to know how much technology is developed prior to the farmer being aware that he needs additional technology and how much actually emerges resulting from the demands of farmers.

Barkley is correct in noting that technology did not cause all of our social ills. I would suggest that it did not cause any of them. If we look behind technology we might discover the cultural values of progress, growth, and development, factors related to the push behind technology. Furthermore, if we probe behind these cultural values, I feel we will discover additional values which can be called greed and the desire for power. Greed and the desire for power are opposite sides of the same coin; and progress, growth, and development are often the clothes they wear in public places. Furthermore, it is futile to blame technology, inflation, and cultural values for the social consequences of human actions. These are only abstract concepts and do not behave. We must blame people who behave in ways which we consider to be greedy, power thirsty, and damaging to specific social groups. Most people who behave in such ways are not evil or wicked; rather, they are people who operate within a structure requiring that they maximize certain values as the price of participation. It is their culture and they know of no other way of viewing the world. After all, the fish will be the last to discover water.

The farmer is caught in such a circumstance. As Barkley notes, he is on the "technological treadmill" and, as an isolated individual, can do little to change his plight short of going out of business. In sum, most farmers have little power over their life situations.

The points concerning the impact of technological change upon rural communities are of increasing importance. As Barkley's own work in Lincoln County, Washington, has portrayed, the socially destructive forces of changes in technology punish entire communities, not simply farmers.

The discussion of the decline in product quality deserves an additional comment. Not only do the new tomato and other such products not taste as good as the old, but there is increasing evidence of a negative relationship between increased productivity and nutrition (Koepf, Pettersson, Schaumann, pp. 370–90). Agricultural scientists on my own campus have informed me that in some grains, the quality of protein declines with increased production. If we feed these grains to animals, the problem may not be of major importance; however, such use of grains is not efficient. If energy resources continue to decline and more grains are produced for human consumption, the relationship between productivity and nutrition will be an important issue and deserves additional consideration in any case. This is especially true in the developing nations where the supply of animal proteins is limited.

In the discussion of backing down on technology, Barkley touches the relevant bases concerning the relationship among land, labor, capital, energy, and the possible impact of change upon rural communities. He is correct in saying that we have little information upon which to base any plans for the future. At this point I get a little lost, I am not clear about the conclusions nor where all of this should lead. Barkley notes that adoption of intermediate approaches will require that a price be paid; but, then again, we pay a price with our current mode of production. A part of the question is who will pay the price and who has the power to exact the price from those who must pay. Furthermore, I would like to know if it is possible to compare the price of current production and distribution with those costs in a system that might emerge with intermediate

technology. Is it possible that we are paying more than we should at the present time? We do know that the farm-retail price spread has widened over the past several years (Hammond, Anthony, Christiansen, 1969). Who benefits and who is disadvantaged by these shifts? I do not know the answers but I admire the questions.

Barkley suggests that it is possible for a limited number of people to backtrack and use more labor but it is foolish to think that all agriculture will follow. While this statement is true, it does not represent the only possible direction for movement. We cannot backtrack, we can only move forward with changes in technology and create criteria for a new and perhaps less massive approach to production and distribution. Such alternatives require exploration. The opportunities for such exploration are available. Small-scale but technologically sophisticated modes of production are successful in Japan and Southeast Asia, and levels of production often exceed those in the United States. Of course, that is Asia and this is North America; nonetheless, we can learn from the experiences of other nations.

Barkley feels that it is unwise to change contemporary policies in regard to intermediate technology or to recommend a movement in this direction to those who train and advise farmers. There is merit in this argument, and we have developed much useful expertise. However, the policy makers and technical advisors may not have a direct voice in these matters. As Sissy Hankshaw noted, our leaders often confuse stability with rigidity, especially when it concerns remaining in power and staying in an advantageous position in the market place. Consequently, we should not expect leadership from these sectors of society in attempting to change our agricultural system unless there is a crisis situation. On the other hand, there seems to be a growing movement concerning a more socially and economically accountable agriculture. Universities are receiving requests for materials on intermediate technology, small-scale production, direct marketing, etc. Training programs outside of the university are emerging, new alternative technology and agriculture journals are available, and students in our agricultural colleges are conducting experiments on new approaches to production. (A guide to literature and resources concerning alternative approaches to agriculture can be found in Esbenshade.) While it is too early to know the outcome of these movements, universities and other public agencies must be prepared to respond to the people who request assistance in their attempts to explore alternative approaches just as they have responded to requests from farmers, agricultural suppliers, food processors, and marketeers.

Finally, I think Barkley is mistaken when he implies that the people who propose alternative technologies all want to return to the past. Most thoughtful advocates of alternative agriculture are more concerned with social and ecological responsibility and feel that it is possible to develop new approaches to our food and fiber needs. This may well require some "high" technology. While such advocates draw upon information from the past, they are working toward a new rather than an old approach to production and distribution. Let's not count them out before we hear what they have to say and evaluate what they have to offer.

Gardner and Pope have provided a nicely crafted paper concerning the current structure of agriculture, primarily drawn from census data. They suggest that changes are not occurring in agriculture as quickly as some would have us believe. While it is heartening to hear that there is still time to make changes in the direction of a more socially and ecologically responsible agriculture, I hope this is not a sign of rigidity, a sign that agriculture has fallen into the hands of fewer and fewer people, as Goldschmidt (p. 305) suggested it might. As Sissy Hankshaw suggested, rigidity takes away the ability to respond to changes. If there is any truth to the claims being made about coming ecological, energy, and population problems, we could be in serious condition because of our inability to react.

Gardner and Pope find that the number of commercial farms are becoming fewer while at the same time increasing in size. They use (as measures of farm size) both the value of products sold and acreage to explore the relative change in scale of operations. In this effort they were successful. However, these measures do not permit an evaluation of changes in the degree of control larger farms have over agricultural production. Such a concern would seem pertinent in any discussion of structure and scale. One appropriate measure is the portion of the total agricultural land controlled by different size-classes of farms, based upon acreage. For example, in a rural California county, roughly one-third of the farms have less than 100 acres, one-third between 100 and 499 acres, and the remaining one-third more

than 500 acres. Such figures do not demonstrate the dominance of large farms. Of a total of 494,331 acres of farm land within the county, the farms with 500 or more acres control 417,368 acres or 86.2% of the total. If we only consider farms of over 1,000 acres, it can be shown that 19.9% of the farms control 75.2% of the land (Moles). This measure tells more about the importance of large farms than do the two used by the authors and would have added to our understanding of the relative dominance of larger units.

In the discussion of the causes of increasing size of farms, it was suggested that there is no clear evidence in a *ceteris paribus* world that demonstrates that price supports and taxes favor large farms over small farms. To the scientist, the world is a *ceteris paribus* world, we simply cannot control enough information to make it otherwise; consequently, I do not believe this is a fair statement. Furthermore, this statement contradicts the assertion by Raup in which he notes that these and other governmental policies are not "scale-neutral." From my own reading, and I admittedly suffer from little formal training in economics, I have found no clear evidence that supports the assertion that such policies are scale-neutral. LeVeen (pp. 22–24) demonstrated in a hypothetical case that price supports reduce the competitive advantages enjoyed by smaller farmers through the use of their own labor. He compared the impact of governmental programs upon different sizes of farms and noted that the larger farmer had a lower percentage net income based upon total receipts than did the small farmer (18% as compared with 37%). The large farm had a total receipt of roughly 17 times that of the small farm, and its total governmental benefits were about 13 times greater. However, the governmental benefits made a major change in the net income of the larger unit. With no support, the net income of the large farm was 3.75 times that of the small farm; however, with the governmental benefits, the net income of the large farm was almost 9 times greater. Consequently, the relative competitive advantage enjoyed by the small farmer was reduced. While this example is only suggestive, additional research along these lines would do much to clarify the issue. I will rest the matter here and hope that Gardner, Pope, Raup, and others will add to our understanding of these issues.

Gardner and Pope explore the suggestion that corporations are "consuming" family farms. They note that, despite a 33.2% increase in corporate farms over the past five years, such farms comprise less than 2% of all farms within the United States. A vast majority of these units are owned by individuals and families. Given this finding, one wonders why all the excitement about the seizure of land by large corporations. One reason for the excitement is that some people feel census data do not provide adequate information to determine the control by nonfamily corporations over agriculture. Gardner and Pope had no alternative but to use census data, but I would like to mention a couple of questions concerning its use. Coffman conducted a national survey in 1968 and reported findings similar to those presented by Gardner and Pope. LeVeen (p. 31), using the Coffman study and the 1969 census, noted that the total production of the small corporations was quite limited. Sixty percent of all corporations (total sales under $100,000) produce 8.5% of all corporate output or about 1.1% of total farm output. Very large farms (total sales greater than $500,000) produced at least 63% of all corporate output or almost 10% of all farm production. Admittedly some of the large farms were individually and family-owned, but they have ceased to behave as do most family-owned units.

Data collection procedures both in the census and the Coffman study have fallen under sharp criticism. Rodefeld conducted a study in Wisconsin to check the validity of the Coffman study. He discovered that Coffman's survey underestimated the total number of acres owned by corporations by 37%, the total number of acres rented by 269%, the number of cattle fed by 80%, the number of brood sows by 216%, and the number of acres in vegetables by 37%. Hightower (pp. 196–97) raised another issue concerning U.S. Department of Agriculture data collection procedures in relationship to corporate farms. He notes that processors produce 10% of all vegetables used in processing plants. Yet these "subsistence" farmers are not counted as farmers because they consume what they produce. Del Monte farms 130,000 acres but is not counted as a corporate farmer. With problems of this magnitude, it is difficult to place much faith in census materials and the Coffman study. If Rodefeld's findings can be generalized beyond Wisconsin, we can conclude that little is known about the dominance of corporate agriculture.

Raup has presented a thoughtful argument concerning the threat to small and intermediate family farms by inflation, rising prices

of farm land, and the advantages large producers enjoy due to governmental programs and access to credit. I have two problems in critically evaluating his paper. First, my training in land economics is almost nonexistent. Second, as has happened in the past, Raup has demonstrated uncommon, common sense. In short, his description of the "economic cannabalism" in agriculture seems to hold true in my own experiences in California. Consequently, my comments will only touch upon a few points. It is redundant to say "me too" in response to statements with which I agree.

A major importance of the paper is Raup's evaluation of the contributions of small and intermediate sized farms to society. After a certain size of operation is reached in which there is a minimal degree of risk, the farmer has the capacity to experiment at a low cost to society. On the other hand, large farms seem to be reluctant to experiment and change. This parallels the observations of Cancian in newly developing nations, where the very poor and the wealthy are not the innovators and leaders in agricultural change. In a society with only small producers, the farmer and consumer may both suffer; while in a society with only large producers, the consumer may suffer at least beyond the point where there is a catastrophic failure in food production. This suggests that large- and small-scale organizations may tend to lead to a rigidity which may appear for a time to be stable but, in the end, be unable to adapt to changing conditions. Medium-sized units are the most responsive to change. Small units can exert little influence over their environment and large units have so much power they tend to behave as though they are impervious to the environment. As any biologist can explain, take away flexibility and the likelihood of survival is reduced. Consequently, if all small and intermediate-sized farms are eliminated, we may be in for difficulty in attempting to adjust to a more energy and ecologically prudent agriculture.

Raup's evaluation of the farmer's "intangible income" is important. Regretably the noneconomists who study the behavior of farmers have little to add to his statements concerning nonmonetary returns. Nonetheless, these returns minimize costs which would otherwise be passed along to other segments of society. Attempts must be made to protect the farmer so he can continue to enjoy these rewards and so that consumers, suppliers, processors, and marketeers cannot take advantage of people who are as interested in the intangible as the tangible rewards of farm life. A real danger exists because there may be no appreciation of the value of the small producer to society by those who have little knowledge of farm life or of the low return to the farmer. Furthermore, I see no real appreciation of "intangible rewards" in much of the contemporary literature in agricultural economics. Consequently, it is possible that the rule of maximum possible tangible return may be enforced in rural America.

Finally, Raup notes that inflation is a major villain in the demise of the smaller farmer. I would like to hear more from the economists concerning the villains behind this villain. I would like to know about the roles of the producers of the inputs used by farmers, of the processors and the marketeers who purchase the goods produced and the advertisers who tell us what to eat. Is there a villain or two lurking here? If the answer is yes, then what should be done about it? Inflation is difficult to deal with as an abstract notion, and we must be prepared to discuss actions or specific types of people which contribute to this phenomenon.

Because of the limitations placed upon the authors, a number of major issues have been neglected concerning the size of farms and the structure of agriculture. If we return to consider the context in which agricultural production exists, an important point has been neglected. That point is the structures with which the farmer must deal, as represented by suppliers of farm inputs and the purchasers of farm outputs. The question is how the scale or size of the organizations which supply the farmer and purchase his products influence the size of farms. Breimyer, in 1964, raised a series of concerns related to the growth in size of organizations which deal directly with farmers and the impact of vertical integration and horizontal combination upon farm size. Later, William Robbins and Hightower voiced similar concerns and suggested the increase in food costs and the decline in food quality can be attributed in part to the emergence of large nonfarm corporations which create new constraints impinging upon farmers. This issue is as important as any other discussed in the papers and must be addressed.

Other factors related to the size of agricultural production units should be mentioned. No attempt was made to discuss the decline in environmental quality which is seen by many

as a justification for small-scale agriculture. Bennett has raised the notion of "sustained yields" in reference to the ideas of protecting the state of natural resources used in production. The danger within the United States is that we tend to be concerned primarily with the product being produced and neglect the land, air, and water which makes such production possible. We must attempt to ascertain whether or not we can maintain a "constant supply" through resource management.

No mention was made of the efficiency of small versus large farms in relation to inputs and outputs or in terms of energy consumption. In fact, energy utilization is another topic deserving more attention.

Stability, flexibility, power, and the context of agricultural production are issues of major importance. The social scientists who deal with farmers must be prepared to speak about those issues. While it is difficult to cope with such abstractions and relate them to an empirical world, we are speaking of the survival and well-being of ourselves and others. It is imperative that we develop the skills and knowledge that will permit a realistic appreciation of the difficult choices that must be made in the not-too-distant future.

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Time Allocation in Rural Philippine Households

Robert E. Evenson

Interest in the time allocation of household members in developing countries is of relatively recent origin. Demographic studies have provided the major impetus for the focus on time allocation as these studies have become increasingly concerned with the costs of caring for children and with the work of children. Efforts are also being made to adapt the general body of modern household economic theory to the low income rural setting. This paper reports an analysis of time allocation data collected from rural Philippine households as part of a larger research effort on agrarian household behavior.

In the language of modern household economics, the time of household members is a resource or factor of production. For poor households, it represents the dominant household resource. It will be allocated to several activities in such a way as to minimize the cost of producing household goods. The first section of this paper develops a relatively simple analysis of factors determining time allocation of household members in rural households. The second section reports a simple econometric analysis of the Philippine data.

Modelling Time Allocation for Rural Households

The household goods model employed in the analysis of fertility and related investment behavior provides a framework for the analysis of time allocation (Becker, Gronau 1973). The full development makes it possible to analyze the choice of household goods and the minimum cost allocation of household resources utilized in the production of those goods. The time of household members will be allocated to home production of each good, to market work, and to leisure in such a way as to minimize the total costs of producing alternative sets of household goods (including leisure). Changes in wage rates, prices of market goods, nonlabor income and fixed home production factors will lead to changes in household consumption and in the allocation of time.[1]

The multiple household good analysis, while critical to the analysis of choice of household goods, is less so for the analysis of time allocation. Here, we concentrate on the allocation of time among home production activities, market or farm enterprise activities, and leisure. In addition, the specialization in time allocation within a household among husband, wife, and children adds complexity not easily handled in the more general household goods model. We will follow Gronau (1976) in utilizing a model with only two goods, a composite consumption good (Z) and leisure. This will allow us to use a geometric approach and to focus more directly on the questions of interest.

The Single Person Household Case

Even though we are primarily interested in the behavior of multiple person households, the single person case affords a simpler exposition of the basic features of the model. Figure 1 portrays several cases of interest. Panel A shows the simplest case, a household with a minimum of resources, in the form of shelter, cooking utensils, and a small home garden, in addition to time. We also will presume that the composite good Z can be produced in the home or purchased in the market. This is a critical assumption because it implies that the mix of home-produced and market-produced goods does not affect the productivity of home production time. In the case of farm produc-

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[1] These models postulate that household-produced goods are arguments in household utility functions. These goods are produced utilizing market goods and home production time of household members. Maximizing utility subject to the full income constraint implies that the household acts as a cost-minimizing firm in the production of household goods.

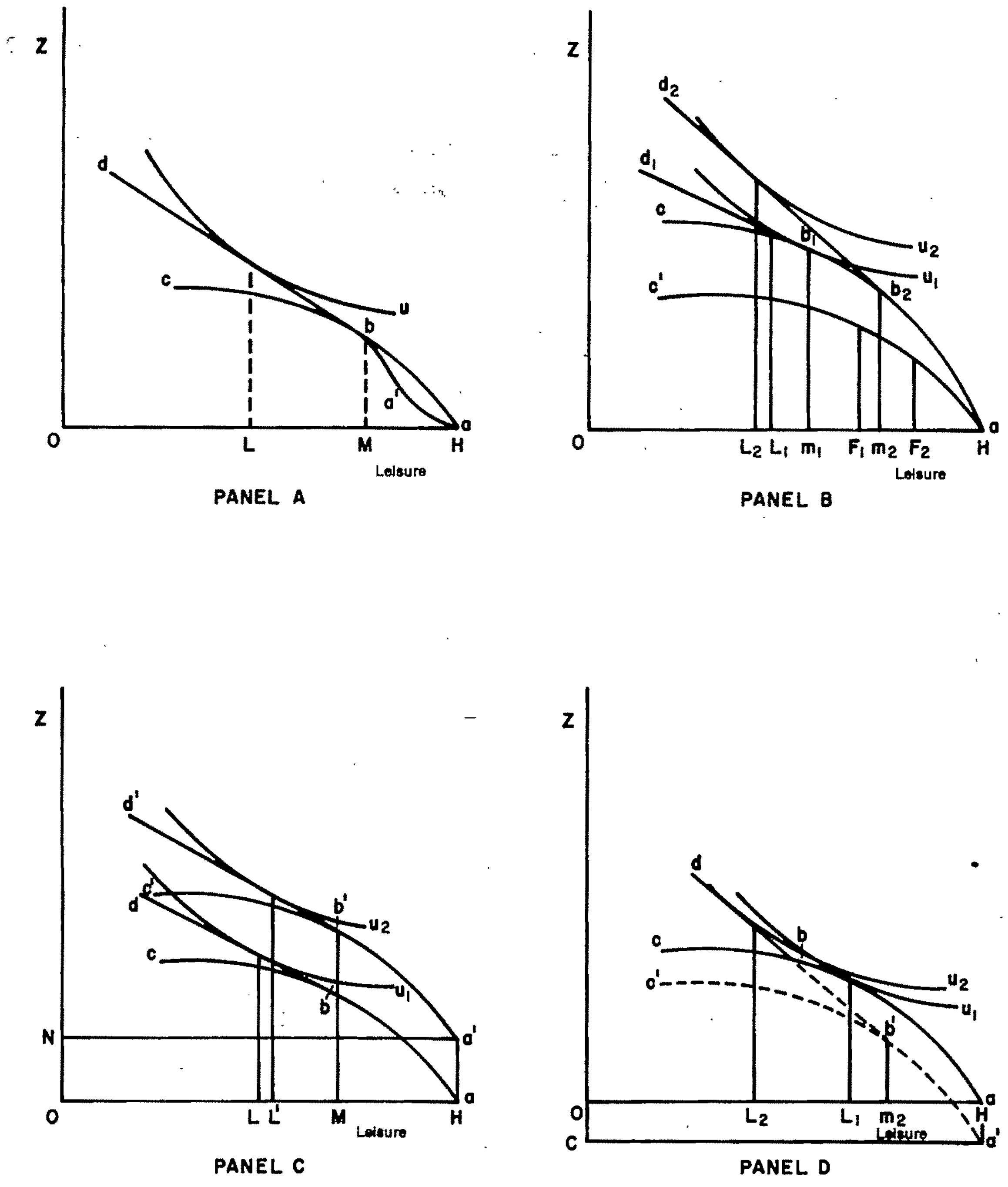

Figure 1. Single Person Household Cases

tion to be considered later, this is not as critical.

The composite good is measured on the vertical axis. Leisure is measured on the horizontal axis. The point H is maximum possible leisure. The curve abc traces out what might be termed a home production curve. Its actual shape depends on other sources of income. If sufficient nonlabor income is available to insure adequate nutrition with no home production, the curve will be as depicted by abc. If this is not the case, a relationship between production and consumption will exist. The curve $aa'bc$ shows a nutrition-work effect in which productivity is low at low levels of production. The home production curve is based

on a work organization in which the most productive tasks are undertaken first. Because of fixed home capital resources, diminishing marginal product is presumed to occur after some point.

The segment db in panel A shows the goods-leisure locus offered by the labor market. The slope of the line is the wage rate divided by the goods price. It is located so that it is tangent to the home production function, reflecting the fact that at points to the left of the point of tangency, b, the productivity of time in the market exceeds that in the home (presuming that home-time is not sold). In equilibrium, the household will devote OL units of time to leisure, LM to work in the market, and MH to home production.

Panel B portrays a household with access to land resources and that engages in agricultural production. The curve ac' is a home production curve as in panel A. The curve ab_2b_1c reflects the combined product from both home production and farm production. Farm production is net of payments to landlords and to variable factors. The segment b_1d_1 again reflects the opportunities afforded by a labor market.

In the initial equilibrium with indifference curve u_1 with market opportunities b_1d_1, this household will have OL_1 units of leisure, L_1m_1 units of market time, m_1F_1 units of farm time, and F_1H units of home time. Note that the marginal product of home, farm, and market time will be equated so the point F_1 is located where the slope of the curve ac' is equal to the slope of the segment b_1d_1.

Panel B also portrays the simple analytics of the consequences of a rise in the market wage. The segment b_2d_2 reflects the higher wage rate. Note that the point of tangency with the combined home and farm production curve shifts to the right from b_1 to b_2. The effect of the rise in wages has two parts. The first is the conventional income and substitution effect on leisure which in this example results in a decrease in leisure from OL_1 to OL_2. The substitution effect is depicted as outweighing the income effect. (This is for convenience of exposition and is not dictated by the theory.) The second part of the effect is the displacement effect against both farm and home time. In panel B, farm time is reduced from m_1F_1 units to m_2F_2 units, and home time is reduced from F_1H units to F_2H units. The relative shapes of the home and combined curves will determine the relative displacement effects against home and farm time. Thus, even if the income effect of a rise in the wage rate outweighed the substitution effect (total leisure increased), the displacement effect could still produce a positive labor supply response. A backward bending supply curve of labor is highly unlikely for a single person household.

Panel C depicts the effects of an increase in nonlabor income. Suppose nonlabor income is increased by an amount sufficient to purchase ON units of goods. The total opportunity curve abd shifts upward parallel to $a'b'd'$. The point b' is directly above b, so the increase in nonlabor income has no effect on the amount of home time (or of combined home and farm time in the case where farm activities are involved). It will increase leisure, however, as long as leisure is a normal good (from OL to OL' units). Consequently, it will reduce market time (from LM to $L'M$ units).

Panel D depicts the effects of fixed job costs. Suppose that costs equivalent to OC units of goods must be incurred in the form of job search and maintenance costs. The relevant opportunity locus in this case becomes abd. With job costs, a certain minimum number of time units will be devoted to market work (if undertaken). Note also that small differences in the indifference curve, or in market wages, can yield large differences in time allocation in certain circumstances. With indifference curve u_1, the equilibrium is OL_1 units of leisure, no market work, and L_1H units of home (or farm and home) time. The indifference curve u_2 produces only OL_2 units of leisure, L_2M_2 units of market work, and M_2H units in the home. A slight rise in the market wage with indifference curve u_1 would have produced a similar effect as the shift from u_1 to u_2 indicates. In the presence of job costs, the "position" of the equilibrium becomes important.

The Two-Person Household

Figure 2 extends the previous analytic framework to the two-person case. (The extension of the analysis to consider children and other household members is taken up later.) Here we are concerned with the economics of specialization within the household.

In panels A and B we depict the single person cases for a husband (panel A) and a wife (panel B) acting independently. The opportunity curves abd are for households without land. The curves $ab'd'$ are for households with

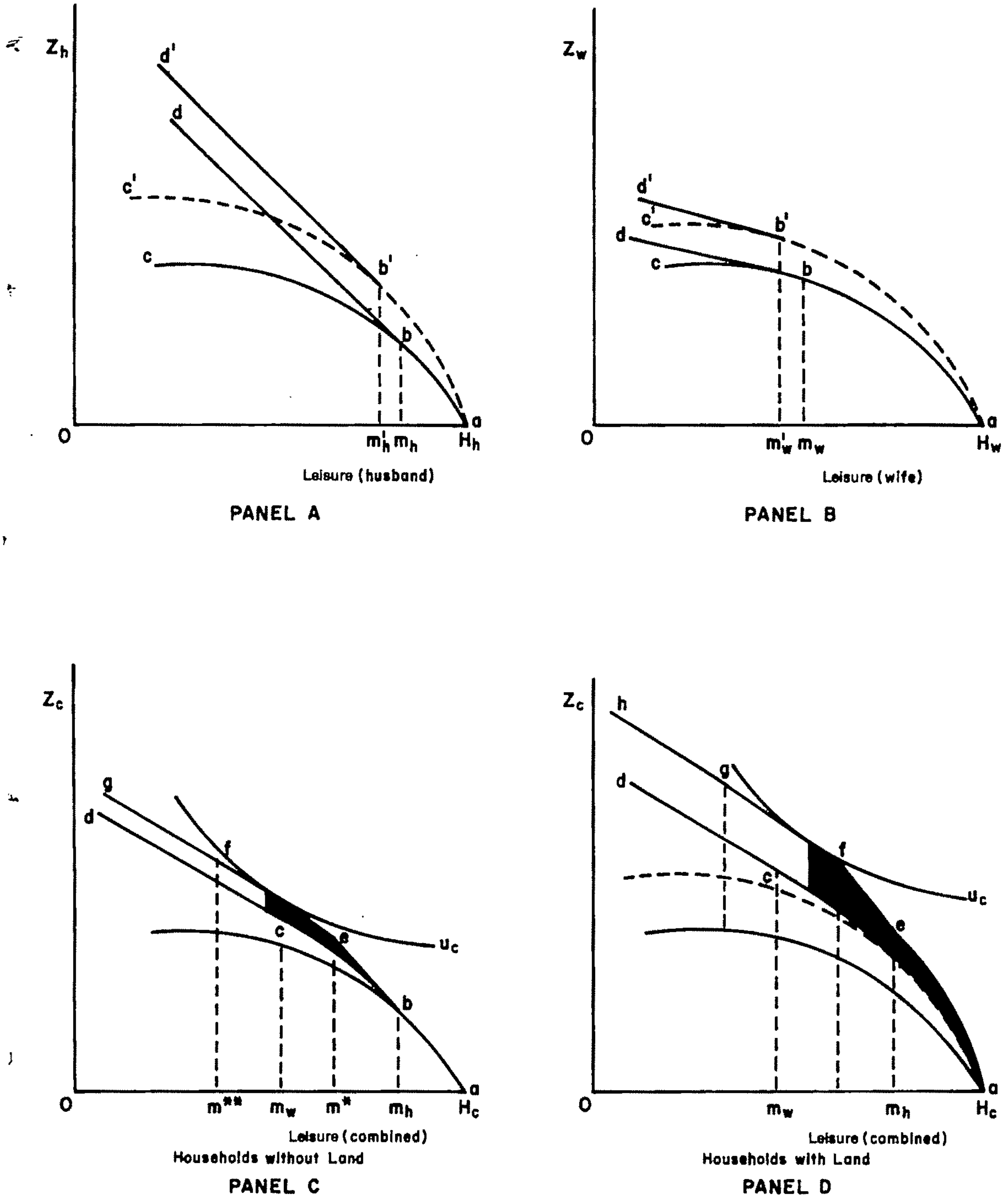

Figure 2. Two Person Household Cases

land. The home production curve for the husband is equivalent to that for the wife. Note, however, that the husband commands a higher wage in the market and is more productive on the farm in this example. This specification is consistent with most empirical evidence.

Panel C depicts the combined household case for landless households. The axis measure goods per member and leisure per member. The curve *abcd* represents the nonspecialization combination and is a simple average of the single goods cases. In the segment

ab both husband and wife work in the home. In the segment *bc* the husband is working in the market, the wife is working at home, while both work in the market in the segment *cd.*

The curve *abefg* represents specialization according to comparative advantage within the household. We suppose here that the wife's time is a perfect substitute for the husband's time in home production. Over the segment *ab*, both will work in the home as this maximizes the combined product. Over the segment *be*, the husband will work in the market. It will now be optimal for the wife to replace her husband's home time. Each additional hour that she replaces allows the husband to work one more hour in the market without changing the leisure of either. The segment *be* in panel C will have the slope of the husband's wage rate and will be the same length as the segment *ab*, because the husband's home time will be replaced entirely.

In segment *ef*, further specialization occurs. The husband will work in the market; the wife will work on both her own and her husband's home production curves. She thus will not enter the market at the point m_w, but at some later point, m^{**}, where her marginal product on both home production curves has fallen to her wage rate. Both will be in the market after this point.

In the equilibrium (given a household utility function) depicted in panel C, the wife does not work in the market. The "gains" from specialization are shown as the shaded area. These gains can be associated with the segment *be* which will be larger, the higher the husband's wage rate and the more productive the wife's home time. The segment to the left of *e* is larger the more productive the wife (in home time), and the more easily substitutable her home time is for her husband's home time. It also is apparent that as the wife's wage is increased, the point m^{**} moves to the right. As the wife's wage rises to her husband's level, the gains from specialization are reduced.

Panel D, figure 2, depicts the combined case for households with land. The curve *abcd* is the simple combination of the single person cases. The curve *aefgh* is based on specialization. Here the specialization begins immediately because of the presumption that the husband is more productive on the farm. In segment *ae*, the wife replaces her husband's home time by equating her own home and farm productivity and his own home production time. She may not fully replace his home time at the point *e*. In the segment *ef* the husband enters the market and the wife further replaces both his farm and home time. Again, because she is less productive on the farm this is a partial replacement so the linear segment *ef* is less than the length of the segment $m_h H$ (on the vertical axis). The segment *fg* is curved because the wife continues to work on the farm and in the home and replaces some of her husband's farm time. At the point *g* she will enter the market but will not have replaced fully the husband's farm time. Gains from specialization are indicated by the shaded area.

A Summary of Expected Effects of Changes in Exogenous Factors on Time Allocation

The combined curves in panels C and D of figure 2 provide a basis for analysis of time allocation of husband and wife. The shifts considered will not be presented geometrically Reference to figure 1 will provide a basis for understanding the effects on the "marginal" household member, taken here to be the wife. Since specialization has in some cases already replaced the home (and farm) time of the husband, the effects on the husband will differ from those suggested by figure 1.

Table 1 provides a schematic summary of the expected effects of changes in exogenous factors on the time allocation of husbands and wives in rural households with and without home enterprise. Each is discussed in further detail below.

An increase in nonwage income. This effect is similar to that analyzed in the single person case. The combined household curve (panels C and D, figure 2) shifts directly upward and has an income effect only on market time if both husband and wife are in the market. In that case, it has no effect on home or farm time. When the wife is not working in the market, an effect on her home time will be expected which could have a small substitution effect because of the curvature of her home production curve. In the case of farm production, both home time and farm time will be affected. When neither the husband nor the wife is in the market, a similar effect will be observed for the husband.

An increase in the husband's wage rate. Such an increase will shift the household curves upward and change the shape some-

Table 1. Expected Consequences of Changes in Exogenous Factors on Time Allocation in Rural Households

	Households without Land				Household with Land					
	Wife's Time		Husband's Time		Wife's Time			Husband's Time		
Exogenous Increase in	Home	Market	Home	Market	Home	Farm	Market	Home	Farm	Market
1. *Nonwage Income*										
W, H in market	0	−I	0	−I	0	0	−I	0	0	−I
W not, H in market	−I*	na	0	−I	−I*	−I*	na	0	0	−I
W, H not in market	−I*	na	−I*	na	−I*	−I*	na	−I*	−I*	na
2. *Husband's Wage Rate*										
W, H in market	0	IS	0	IS	0	0	IS	−D*	−D*	IS+D*
W not, H in market	IS*	na	−I	0	−IS*	−IS*	na	−D	−D*	0
W, H not in market	0	na	0	na	0	0	na	0	0	na
3. *Wife's Wage Rate*										
W, H in market	IS−D	IS+D	0	−I	IS−D*	IS−D*	IS+D*	0	0	IS
W not in, H in market	0	na	0	0	0	0	na	0	0	0
W, H not in market	0	na	0	na	0	0	na	0	0	na
4. *Wife's Home Productivity*										
W, H in market	+D	I−D	0	−IS*	+D*	+D*	−I−D	+D	+D	−I−D
W not in, H in market	IS	na	0	−IS*	+D*	+D*	na	+D	+D	−I−D
W, H not in market	IS	na	IS	na	+D*	+D*	na	−I	−I	na
5. *Farm Productivity*										
W, H in market					−D	+D	IS−D	−D	+D	IS−D
W not in, H in market					IS−D	IS+D	na	−D	+D	IS−D
W, H not in market					IS−D	IS+D	na	IS−D	IS+D	na

Note: I is income effect; IS is income effect and substitution effect; D is displacement effect; and * is limited effect.

what. In contrast to the single person case, there is no home-work displacement effect, except in the landed household case where we can suppose that the wife's productivity on the farm is lower than that of her husband's. There is an income and substitution effect (*IS*) on the market time of the husband with the substitution effect dominating. In the case of farm production, a small displacement effect is observed and a modified income and income substitution effect on the wife's time is expected, depending on the sharing of leisure.

An increase in the wife's wage rate. Here, there is no consequence unless the wife is actually working in the market, in which case the effect on her time will be similar to that for a single person household, a displacement of home (and farm) time will be involved. Where substantial job costs were involved, new entrants would displace a considerable amount of home time (figure 1, panel D). The effect of fixed job costs is to extend the length of the third segment of the curve in figure 2, panel C.

An increase in the home productivity of the wife. If the wife becomes more skilled in home production or the household chooses to produce more goods with a high "home time intensity" (such as child services, discussed in the following section), the combined household curve will be raised. Thus, the effect of an increase in the wife's home productivity (holding her wage constant) will include an income effect on leisure and possibly a substitution effect, but this depends on the shape of the home production curve. It will make it less likely that she will work in the market. However, if she does work in the market, it will have an income effect and should increase both her own and her husband's leisure.

An increase in farm productivity. A shift in farm productivity shifts the household curve upward and extends the segments associated with farm work (panel D, figure 2). This displaces market work for those already in the market and so makes it less likely that either partner will engage in market work.

The effect of children. The effect of children in the household can be thought of as having three components: (*a*) a household life cycle effect; (*b*) a goods effect which comes from the fact that child services are relatively home-time intensive goods; (*c*) a work effect which comes from the fact that children's time can be employed in home and market production.

The life cycle effect is associated with the timing of the other two effects. When children are young, they contribute little to home production; and because they are home-time intensive in the mother's time, their effect is to raise the home production curve. During a middle life cycle stage, when there are both

Table 2. Time Allocation Data: Hours Per Week, Summary of 225 Households

	Households with			Households with		
	No Land (113)	0–1 Hectare (40)	Greater Than 1 Hectare (72)	Pre-school Children Only (45)	Pre-school & School Children (102)	School Children Only (78)
Husband's time						
Food preparation	1.4	1.6	1.6	1.8	1.5	1.2
Care of children	3.8	1.9	2.2	5.2	3.5	.9
Total home time	9.0	6.6	8.8	9.8	12.0	10.9
Wage work	23.8	10.9	7.6	13.6	17.5	16.4
Farm work	4.6	9.6	11.6	8.0	7.1	8.3
Total market work	28.4	20.5	19.2	21.5	24.7	24.7
Wife's time						
Food preparation	20.9	18.8	20.3	22.1	21.2	18.2
Child care	10.5	14.5	11.0	18.1	14.9	2.8
Total home time	42.4	48.2	45.0	54.3	49.6	31.5
Wage work	3.4	5.4	2.4	1.8	2.8	4.6
Farm work	3.8	2.6	3.6	1.5	3.5	3.8
Total market work	8.0	8.6	5.9	4.5	6.0	9.3

younger and older children in the household, there is an effect of increased home production, as discussed, and another effect associated with the addition of children as workers, roughly equivalent to the addition of a second person. Just as the wife displaced her husband's home production time to enable gains from specialization, older children will replace the home production time of the wife in certain tasks. At a still later stage in the life cycle when only older children are present, specialization effects will dominate.

Preliminary Empirical Tests Based on Philippine Data

We report in this section results of preliminary analyses of determinants of time allocation based on a sample of 225 rural households in Laguna Province in the Philippines, one of several collected in the Laguna project (Evenson and Popkin, King-Quizon). The Laguna project collected data over a two-year period. Both recall and participant observation methods were utilized. The sample investigated here is a recall sample from a resurvey in 1977 of households included in a 1975 sample.

Table 2 presents a summary of the data in terms of the average hours per week of time allocated to certain tasks. It can be noted that most husbands do engage in an appreciable amount of home production time, particularly in gardening. The amount of farm work appears to be relatively low for these households.[2] The table indicates that land cultivation is associated positively with farm work but negatively with total market work of the husband. It does not indicate an association of the home time of either the husband or wife with cultivated acreage. The effect of the age structure of children on the child care time of the parents is indicated, however.

Table 3 summarizes the results from the regressions used to test implications of the previously developed models.[3] The regressions, investigating determinants of the market time of husbands in both farm and nonfarm households, have moderately high R^2 statistics. The regression explaining the wife's farm time in the farming household sample, on the other hand, offers little explanatory power.

Many of the coefficients in table 3 are not significantly different from zero, but reference to table 1 will indicate that many are not expected to be. We summarize the empirical results below.

Nonwage income is expected to have a significantly negative impact only on the husbands' market time in the nonfarming households and this is borne out by the regressions. The data do not support the hypothesis for the farming households, however. Farmers possi-

[2] These data suggest less market work than other samples in the Laguna project. A full comparative analysis of data collected utilizing different methods will attempt to investigate biases in the data.

[3] Simple OLS estimates are not the most efficient estimators because the time and the income constraints can be utilized to derive restrictions across equations.

Table 3. Regression Analysis: Time Allocation Data in the Rural Philippines

	Dependent Variables									
	Nonfarming Households (101)				Farming Households (124)					
	Wife		Husband		Wife			Husband		
Independent Variables	Home time	Market time	Home time	Market time	Home time	Farm time	Market time	Home time	Farm time	Market time
Nonwage Income	−.00004	.00006	.00084	−.00004^{xx}	.098^{x}	.014	.045^{x}	−.002	−.009	.012
Wife's Market Wage	−1.085^{x}	.983^{xx}	−.474^{x}	−.796^{x}	−.32	−.76	.708^{xx}	−.014	.155	.035
Husband's Market Wage	.091	.015	.007	.336^{xx}	.275	−.56	.069	−.014	−.336^{xx}	1.01^{xx}
Home Capital	.0018	.0018	.0004	−.0003^{x}	.00025	.0005	.00005	−.00005	.0005^{xx}	−.0001
Farm Capital					.0005	.0003^{x}	−.0003^{x}	−.0005^{xx}	−.0004	−.58^{x}
Farm Replacement Wage—Wife					.0276^{xx}	.0063^{xx}	−.060^{x}	.002	.002	.0046
Farm Replacement Wage—Husband					.020′	−.0002	−.0098^{x}	−.0004	.084	−.002
Cost of Market Job		.208		3.17^{xx}			.049			.009
Children 0–3	−2.99	−4.53	3.19	−2.61	6.16	−1.48	−3.55^{x}	.98	.30	−4.22
Children 3–6	1.67	−2.05	.009	1.37	7.19^{x}	1.98	−1.36	−.28	2.55	.34
Children 6–9	−2.65	4.16^{x}	−.25	5.36^{x}	−4.04	−.10	4.82^{xx}	.13	−1.31	.31
Children 9+	−5.40^{xx}	1.43	−1.14	−.61	−.55	−.08	.27	−.22	−.94	.78
Education of Wife	−.25	.16	−.67^{xx}	.27	.42	−.46	.085	.27^{x}	−.30	.21
Education of Husband	−.66	−.20	.54^{xx}	.56^{xx}	−1.53^{xx}	.52	.031	−.093	.23	.61^{xx}
Year Married	.61^{xx}	.15	−.016	.29^{x}	.51^{x}	.80	.05	.13	.36	.21
Days Sick	.339	−.03	−.011	−.033	−.607	−.282	−.20	.38^{xx}	.067	−.07
R^2 (Unadjusted)	.331	.226	.237	.550	.297	.157	.508	.452	.291	.459

Note: x indicates the coefficient is 1.5–2 times standard error; xx indicates the coefficient is more than twice the standard error.

bly are using nonfarm income sources to improve farm and home productivity.[4]

The estimated impact of the wife's wage is consistent with expectations. The model predicts a strong positive effect on the wife's market time and a negative effect on home and farm time. The estimated coefficients for the market time impact are several times their standard errors.

Similarly, the strongest implications for the husband's wage are supported by the data because the market wage coefficients are several times their standard errors. The expected negative effect on home time in nonfarming households is not borne out, however.

The estimated effects of home capital are of the right sign but have low statistical significance. This variable is measured as the value of houses and household appliances.

The farm capital variable is designed to pick up the farm productivity effect. The positive effect on farm time is borne out for the wife, but not for the husband. Negative effects on market time are borne out.

The replacement wage effects for farm work are as expected but are not generally significant.[5]

The costs of maintaining a job lead to higher amounts of market work, as expected.

Education impacts are difficult to interpret, but they appear to reflect the fact that schooling enhances productivity and possibly lowers costs associated with market work relative to home and farm work.

Child variables generally show the expected pattern: younger children increase home time and decrease market time; older children have the opposite effect.

This analysis is based on a very simple model. The econometric tests are likewise simple. In future work with the full data set from the Philippines, we plan more complex model building and econometric techniques. We will also undertake further analysis of the quality of the data.

It is tempting to argue that one should eschew the simpler modeling and concentrate on more sophisticated procedures. However, this

[4] In this analysis, home and farm capital and nonfarm income variables are measured as of 1975, i.e., based on the earlier survey. This is done because the degree of endogeneity is less than for currently measured variables.

[5] In cases where market work is not undertaken, market wages are given a value of zero as they have no expected effect. Replacement wages are designed to reflect alternative costs for farm work. When family workers were employed, farmers were asked to estimate the wage which would have been paid to a hired worker.

is a field of analysis that is still in its infancy, particularly as it relates to rural households in developing countries. Simple models, such as those explored in this paper, may be more useful at this stage than more elaborate ones, given the paucity of empirical information.

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Household Allocation of Voluntary Labor in the Production of Fire Protection: Minnesota Evidence

Thomas F. Stinson

Volunteers and the services they provide play a significant, but largely unnoticed role in enhancing the quality of life in the United States. The most recent survey of voluntarism conducted by the Bureau of Census for ACTION estimated that more than 37.4 million people volunteered time to some community project during 1974. Wolozin, using a different data base, estimates that volunteers contribute between $25.5 and $26.4 billion to the national economy. Without this large volunteer effort fewer collectively consumed goods would be available, and would cost considerably more. Both the scope and the amount of public services available have been increased through volunteer labor. Weisbrod even argues that voluntarism is an important vehicle through which those receiving less than optimal amounts of collectively consumed goods can increase their consumption.

Despite its importance voluntarism has received little attention from economists. Only recently have serious attempts been made to examine this issue, and most of that work has concentrated on the social accounting problems of estimating the number of volunteers and their contribution to the national economy. As a group economists have virtually ignored the decision to volunteer and the issues surrounding it.

This study examines the individual's decision to volunteer labor to produce local government services. The focus may appear narrow. However local governments, especially smaller cities, use a great deal of volunteer labor. Indeed for only one service, local fire protection, the National Commission on Fire Protection and Control, in *America Burning*, estimated that volunteers provide services valued at more than $4.5 billion.

This paper includes two major sections. First, the household production model is extended to include the time volunteered to produce a collectively consumed good. The approach used ascribes a high degree of economic motivation to the individual's decision to volunteer. While noneconomic considerations certainly have some impact on those decisions, here they are assumed to play only a minor role.

Empirical testing of this form of the household model would require extensive primary data collection. To reduce the data problems, a simple model of community decision-making is proposed which retains the essential characteristics of the household model while allowing the model to be estimated using data on community characteristics.

The second section of the paper presents the results obtained when the community choice model is used to determine the effect that differences in key socioeconomic characteristics of the community have on the way a community chooses to staff its fire department—volunteer, mixed volunteer and full time, or all full time—and the percentage of the staff that are employed full time.

The Theoretical Framework

The household production function suggested by Becker incorporates time into the individual's utility maximization process. That model in its simplest form states that individuals do not derive utility directly from the goods they purchase, but rather from what are termed commodities. Purchased goods as well as household time are treated as factor inputs in the production of each commodity. Each household can then be thought of as allocating

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time between the market work necessary to purchase the goods needed to produce the commodity and the consumption time required for each commodity.

This framework for analysis has proved to be rich in empirical applications. Studies based on it have been conducted on a number of topics, most prominent among them the economics of the family and the value of housewives' time (Schultz, Gronau). In this section the household production model is expanded slightly to allow the analysis of individuals volunteering their time to produce local government services. The key to this extension is removing the restriction limiting the analysis to privately consumed goods. The collectively consumed good may be produced by using donated or nominally paid labor and professional labor in any combination. However, the price of the service increases directly with the amount of professional labor used. For completeness, the individual is also allowed to derive satisfaction from volunteering time, although this is not vital to the empirical section of the paper.

More formally, consumers are assumed to have a utility function of the form

$$U = U(G^{\circ}, Z, V),$$

where G° represents the locally produced public service, a commodity which may be produced using volunteer labor; Z represents all other commodities; and V represents the amount of time volunteered to produce commodity G. The amount of G available for consumption is assumed to be fixed and determined exogenously through the political process.

Utility is maximized subject to constraints on income and time and the household production function for Z, i.e.,

$$\begin{aligned} Y &= WH = P_x X + P_G(V), \\ T^{\circ} &= H + L + V, \\ Z &= Z(L, X), \end{aligned}$$

where Y is income; W, the wage rate; H, hours worked; P_x, the price of X; T°, total time available in the period; and P_G, the price paid for commodity G°; and L and X, the amounts of time and market goods used in producing Z.

The price of G°, $P_G(V)$ requires further explanation. Unlike prices in traditional budget constraints, it is not a single price. Instead, it is a schedule of prices that depends on how much labor one volunteers to the production of the service. Each individual faces a different price schedule, depending on his facility for producing G. All households are assumed to be able to make accurate assessments of their productivity.

Prices may also differ among individuals depending on the way G is financed. If, for example, G is produced by local government and financed by property taxes, the price for each individual will depend in part on the amount of property he owns. Or, if the charge is based on the number of children participating in the activity, larger families will pay more than smaller ones.

Finally, the price schedule for G is a set of expected values. It is the amount an individual expects to pay for G, given different amounts of his volunteer time, taking into account one's best estimate of the amount of time volunteered by others.

Making the appropriate substitutions the utility maximizing system becomes

$$\begin{aligned} U = {} & U(G^{\circ}, X, L, V) \\ & - \lambda[(T^{\circ} - L - V)W - P_x - P_G(V)]; \end{aligned}$$

and, for present purposes, the relevant first order condition is

$$\partial U/\partial V - \lambda P'_G(V) = \lambda W,$$

where $\quad P'_G(V) = \partial P_G/\partial V < 0.$

Focusing on this condition, it is apparent that to maximize utility, an individual must volunteer time to the point at which the marginal utility associated with the last unit of time spent in volunteer work is equal to the marginal utility of the income derived from the last unit of time spent at work.

As indicated, volunteers derive utility from two sources. First, there is the direct satisfaction, represented by $\partial U/\partial V$, obtained from either the act of volunteering or the results of one's efforts. This direct consumption component of voluntarism is what usually comes to mind as the reason individuals volunteer. It includes the satisfaction derived from volunteering for social, cultural, status, and sense of duty reasons. Unfortunately, such satisfactions are difficult to measure, and we lack the necessary knowledge about systematic variations in these satisfactions to incorporate them into any predictive model.

Volunteer work may also produce utility indirectly. For some services when one volunteers his labor, the price he must pay to receive the service is reduced, thus freeing earned income to be spent elsewhere. This reduction in the

cost of service, $P'_G(V)$, can be thought of as an implicit or shadow wage earned by the volunteer. Often this shadow wage is composed primarily of tax savings.

For some of the services provided by volunteers, especially those provided by local governments, this reduction in the cost of the service may be the primary source of utility. It is on one of these services, fire protection, that the empirical work will be focused. For ease in exposition, the utility derived from the act of volunteering and the service provided will be ignored. The rest of the discussion concentrates only on the shadow wage available to volunteers and the opportunity costs of their time.

The utility maximizing solution when the wage rate is constant and there is no limit to the number of hours which may be worked at the market wage is illustrated in figure 1. Here, the slope of line AB is the wage rate, the slope of curve BC represents the value of marginal product for volunteer time, or the shadow wage, and U is the indifference curve between income and leisure. The first order conditions indicate that utility is maximized at the point at which the marginal utility of leisure is equal to the marginal utility of income from either market work or from volunteer work in the production of G. In this situation an increase in W, other things equal, yields a decrease in the amount of time volunteered.

By focusing on the determinants of the shadow wage and the conditions under which it may change a great deal may be inferred about the supply of voluntary labor. For example, for fire protection, individuals who own more property have a higher potential shadow wage. Without a volunteer fire system these citizens would either have to pay more property taxes to support a paid fire department or risk a larger than average loss in case of a fire. Owners of local businesses and commercial establishments are the most obvious members of this group since they have both their homes and businesses to protect and pay property taxes on. Casual examination of local volunteer fire department rosters confirms there is a high degree of participation from this group.

The model presented in figure 1 is overly simple, however. Individuals do not face a constant wage rate, and they do not have the alternative of working every hour of the time period. It is probably more useful to examine the implications of parameter changes in a framework in which there are institutional restrictions limiting the number of hours one can work at his regular job, and in which the marginal wage rate declines after some point. This situation is represented in figure 2.

Now the slope of line AB is the wage rate for the first t hours of work. The slope of BC is the marginal wage rate for additional hours worked, and BD is the shadow wage rate for the production of G. In this situation the effect of a change in the market wage on the amount of labor cannot be determined. It is apparent, however, that an increase in the part-time employment wage rate will affect the number of hours volunteered only if the new wage exceeds the shadow wage of volunteer time. If that occurs, there will be a one to one substitution between hours worked and hours volun-

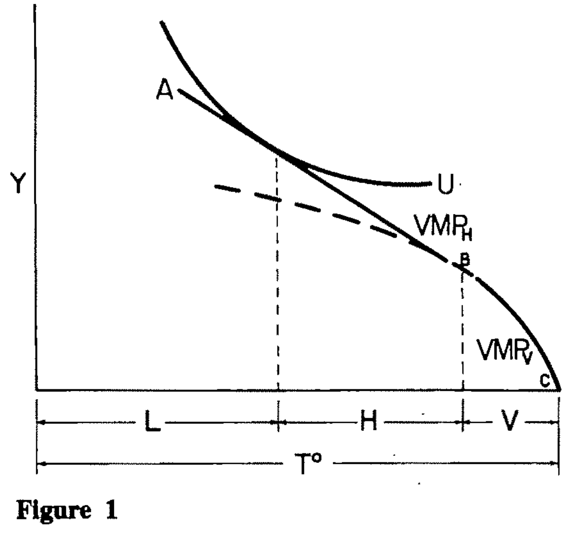

Figure 1

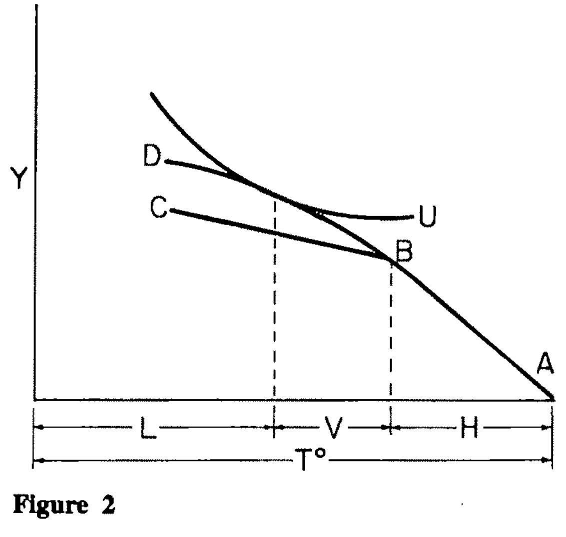

Figure 2

teered. In this framework the wage rate no longer has an unambiguous effect on volunteer time offered by the household. The model does not, however, invalidate investigation of the determinants of the shadow wage as a way of learning more about the characteristics of volunteers.

While the above framework allows the estimation of a labor supply function for voluntary labor, data requirements would make it a very expensive undertaking. One would be forced to collect time budget data from individual households.

However, the special nature of the set of services under consideration, services provided by local governments, offers an alternative approach. If the individual model can be incorporated into a simple community choice model without losing its essential characteristics, data on community characteristics and fire department staffing can be substituted for measures of the individual's characteristics and time volunteered.

We begin with the observation that a service using volunteer labor is less costly than one using professionals. Assuming equal quality of service, all members of a community then will prefer to have the service provided by volunteers (other than themselves), not professionals. Consequently, the community will choose to use volunteers unless insufficient volunteers are available to provide the service. In probability terms, it may be stated that the probability that a service is provided by volunteers is equal to the probability that the number of volunteers is greater than or equal to some critical number N^*:

$$Pr(Vol) = Pr(NV \geq N^*).$$

This condition eliminates the possibility for a community to choose the use of volunteers when no one is willing to volunteer.

The household model indicates that the probability any individual will volunteer depends on his shadow wage and the opportunity cost of his time,

$$Pr(X_i\colon vol) = f(SW_i, OC_i),$$

where $\partial Pr/\partial SW > 0$ and $\partial Pr/\partial OC < 0$.

Finally, the probability that any community will obtain enough volunteers to provide the service depends on the shadow wage and the opportunity costs of time for each individual in the community.

$$Pr(NV \geq N^*) = F[(SW_1, OC_1), (SW_2, OC_2), \ldots, (SW_n, OC_n)].$$

If we assume everyone in the community can be represented by the means over individuals or households, then

$$Pr(NV \geq N^*) = F(\overline{SW}, \overline{OC})$$

This model is estimated in the following section.

Empirical Results

The community choice model indicates that the probability that a city will use paid full-time firemen is directly related to the opportunity cost of the local resident's time, and inversely related to the shadow wage available to volunteers. This section presents the results obtained when that model was applied to community decisions on staffing fire departments. Probit analysis was used to examine the effect that the shadow wage and opportunity cost of time have on the probability that a city employs at least one paid, full-time fireman. Probit analysis was also used to estimate the effect of these variables on the probability that cities with at least one full-time fireman would have a full time fire department. Tobit analysis was used to estimate the effect of the shadow wage and opportunity cost of time on the percentage of full-time firemen in the city's fire department.

Data

Median family income in 1970 (*MEDY*) was used as a crude measure of the opportunity cost of time in the community. While there are a number of problems with this measure (for example, the earnings of other members of the household are not separated from those of the primary wage earner and the measure reflects the average rather than the marginal wage rate) no better surrogate of the marginal wage rate of the head of household was available.

Two additional variables indicating the potential number of fires per year were also included since the opportunity cost associated with fighting three or four fires a year is likely to be much less than that associated with fighting thirty or forty. Those variables were the number of housing units in the community in 1970 (*NUNITS*) and an index of local housing quality (*INDEX*). The quality index was derived through a principal components analysis of six measures of the quality of the local housing stock—median value of owner-occupied housing, median rent, percentage

renter-occupied, percentage built before 1950, percentage with full plumbing, and the percentage with complete kitchens.

Two variables served as measures of the potential shadow wage, the ratio of the assessed value of the average home to the total assessed valuation of the community (*TAXPRICE*) and the percentage of the work force self-employed (*SEMP*). As indicated above, individuals with their own business have higher potential shadow wages for property tax-financed services because they pay taxes on both their business and residential property. As a result one would expect, *ceteris paribus*, that as the percentage of self-employed increased, the probability of having a paid department would decrease.

TAXPRICE, the ratio of the assessed value of the average home to the total assessed value of the community, can be thought of as the relative tax cost to the individual of an additional dollar of locally raised revenue. If the tax cost to an individual is very small, as it would be in a community where industrial or public utility property is a major portion of the tax base, individuals again would be less likely to volunteer and a paid department more likely to be observed.

Two other variables were included in the estimating equation—a dummy variable (*TCSUB*) indicating whether or not the city was in the seven county Minneapolis-St. Paul metropolitan area, and a dummy variable (*TCENTER*) indicating whether or not the city was classified as a full service shopping center in the Upper Midwest Economic Study (Borchert and Adams). These variables were included because access to part-time employment might be better in these areas, thus affecting the opportunity cost of time. Trade centers and twin cities suburbs may also have a slightly different self image which could influence the way their fire department is staffed.

Data on median family income, the percentage self-employed, and housing characteristics were obtained from the 1970 Census of Population and Census of Housing. Information on average assessed values and total assessed valuation was obtained from records of the Minnesota Department of Revenue. The Minnesota Fire Information, Research and Extension Center provided data on the number of paid and volunteer firemen in each community. The complete sample included 143 Minnesota cities ranging in population from 2,500 to 100,000.

The same measures of shadow wage and opportunity cost of time were used for all three sets of estimates. The only difference was that one of the dummy variables, *TCENTER*, was omitted from the probit analysis of full-time departments due to multicollinearity.

Results

Results obtained from the probit analysis of cities with fire departments that are completely volunteer or mixed volunteer and paid are presented in table 1. Measures of the potential shadow wage, *TAXPRICE* and *SEMP*, were both statistically significant at the .01 level. These variables and the opportunity cost variable *INDEX* contributed most of the explanatory power of the equation. The other opportunity cost measures, *MEDY* and *NUNITS*, were not statistically significant, and the sign of *NUNITS* was not as hypothesized. While neither of the dummy variables, *TCSUB* or *TCENTER*, were statistically significant, their *Z* scores were much greater than those for *NUNITS* and *MEDY*. In addition, while there was no firm hypothesis about sign, their positive signs were intuitively appealing.

The change in the conditional probability of a city employing at least one full-time fireman, associated with a 10% increase from the mean for each independent variable (while the others are held constant at their means) is also given in table 1. In general the changes in probability are small. *TAXPRICE* and *SEMP* have the largest impact, increasing the probability by between .01 and .02. When the values

Table 1. Probit Results, Full Volunteer to One or More Full-Time Firemen, Minnesota Cities, 1970

Independent Variable	Z Score	Change in Conditional Probability[1]
NUNITS	−.282	−.0006
INDEX	−2.474	−.0001
MEDY	.356	.0052
TAXPRICE	−2.632	−.0182
SEMP	−2.782	−.0117
TCENTER	1.626	.005
TCSUB	1.723	.0186
CON	.173	—

Note: $n = 131$; predicted probability given all values at mean .0415; −2 log likelihood ratio test statistic 50.55.

[1] Changes in conditional probability for continuous variables were computed for a 10% increase from the mean value of the variable, all other variables held at mean. For the discrete variables *TCSUB* and *TCENTER*, a one unit change was used.

for *TCENTER* and *TCSUB* are allowed to change from 0 to 1, the associated changes in probability are also small.

The results from this analysis lend support to the household production analysis of voluntarism even though the model was not tested directly. They also cast considerable doubt on the simplest alternative for explaining why some cities use all volunteers and others have some paid, full-time firemen. The use of full-time firemen cannot be attributed simply to population differences or differences in population and income. The insignificant coefficients on both *MEDY* and *NUNITS* force rejection of that hypothesis.

When the choice between mixed volunteer and paid, and full professional departments was analyzed, the results were different (table 2). *NUNITS* and *MEDY* were both significant at the .05 level as was *SEMP*. *TAXPRICE* and *INDEX*, variables that were significant for the choice between all volunteer and mixed volunteer and paid departments, were not significant. *TAXPRICE* did not even have the hypothesized sign.

Due to multicollinearity only one of the dummy variables could be included. *TCSUB* was statistically significant. Its negative coefficient indicated that outstate communities are more likely to have full-time fire departments, given they have at least one paid full-time fireman, than cities in the seven county metropolitan area.

The estimated changes in probability in table 2 should be interpreted as the change in probability of having a full-time fire department, given that the city already has at least one full-time fireman. Again, the changes in conditional probabilities are based on a 10% increase from the mean value of the independent variable, all other variables held at their means. *MEDY* had the largest associated change of the continuous variables, .16. When the continuous variables were held at their means, changing the value of *TCSUB* from 0 to 1 decreased the probability of having a full-time fire department by .99.

When the log-likelihood ratio test was used to test whether variables other than *MEDY*, *NUNITS* and the constant added any explanatory power to the model, the results were negative. As a result for this group the community choice-voluntarism model cannot be distinguished from the simple income-population explanation of the community decision to use a full-time fire department.

Tobit analysis was used when the volunteer model was used to estimate the expected percentage of full-time firemen in the city's fire department. Ordinary least squares regression was not appropriate in this instance since there were a large number of observations of zero full-time firemen. The Tobit model, which combines the properties of multiple regression and probit, handles this problem more adequately (Tobin).

Results of the Tobit analysis are presented in table 3. All measures of the potential shadow wage and the opportunity cost of time were statistically significant, with all but *MEDY* significant at the .01 level. Neither of the dummy variables were significant however.

The third column in the table, the elasticity

Table 2. Probit Results, One or More Full-Time Firemen to Complete Full-Time Fire Departments, Minnesota Cities, 1970

Independent Variable	Z Score	Change in Conditional Probability[1]
NUNITS	2.410	.0497
INDEX	−.836	−.0003
MEDY	2.464	.1599
TAXPRICE	1.27	.0175
SEMP	−2.556	−.0756
TCSUB	−2.615	−.9999
CON	−2.093	

Note: $n = 43$; predicted probability given all variables at mean = .0995; −2 log likelihood ratio test statistic 39.36.

[1] Changes in conditional probability for continuous variables were computed for a 10% increase from the mean of the variable, all other variables held at the mean. For *TCSUB* the conditional probability is for the change from suburb to outstate community.

Table 3. Tobit Results, Percentage of Fire Department Employed Full Time

Independent Variable	Z Score	Elasticity of Expected Value[1]	Elasticity of Predicted Probability[1]
NUNITS	2.952	.889	1.26
INDEX	−3.788	.024	.34
MEDY	2.005	4.67	6.61
TAXPRICE	−2.948	−2.88	−4.08
SEMP	−3.717	−3.54	−5.02
TCENTER	1.227	.236	.334
TCSUB	−.289	.112	−.159
CON	−.942		

Note: $n = 143$; mean squared error for $E(Y) = .04$; mean absolute error = .002; predicted probability of $Y > 0 = .096$; $E(Y)$ at mean values = .019.

[1] The elasticity for each independent variable was computed with the other variables held constant at their means.

of predicted probability, contains essentially the same information as one would receive if probit analysis had been conducted on the city's choice between a volunteer department and a department that employs any full-time firemen, including departments staffed entirely by full-time firemen. *MEDY, TAXPRICE,* and *SEMP* all have elasticities with absolute values greater than 4.0 for changes from the mean.

The second column, elasticity of expected value, provides estimates of the effect that a change in any of the independent variables has on the expected percentage of the fire fighting force employed full time. As with the probit results, the non-linear estimating technique makes these estimates valid for only small deviations from the mean of the particular variable, given that all other variables are held at their means. Again the absolute values of the elasticities were greatest for *MEDY, SEMP,* and *TAXPRICE.*

The Tobit results provide additional support for the household production model of voluntarism. The log-likelihood ratio test indicated that the explanatory power of the full model was significantly greater than that of a model relying on simply population and income. Further, the fact that all measures of the opportunity cost and shadow wage included in the Tobit regressions were statistically significant is encouraging evidence that the potential shadow wage is an important factor affecting the amount of labor volunteered for the production of local government services.

Conclusions

Although use of the volunteer-community choice model to estimate the probability of a city having a paid fireman or a full-time fire department cannot be considered to be a full test of the household voluntarism model, the results obtained encourage further study. Additional testing of the model using individual or household data is necessary. But, it appears that the basic household production model can be applied with minor modification to the analysis of voluntarism. This framework for analysis is certainly more useful for those services where the marginal utility obtained from volunteering does not dominate the potential shadow wage. However even for situations where the shadow wage is relatively small, the model appears to be a useful analytical tool.

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The Demand for Home-Produced Food by Rural Families

Henry Kinnucan and Benjamin Sexauer

Utilization of home production as a way of satisfying household food needs has declined dramatically throughout much of this century in the United States. About one-fifth of the retail value of all food consumed by U.S. civilians was produced by the consuming household in 1929. This proportion dropped to around 7% by 1959 (Burk, p. 91). The average annual retail value of food raised for home consumption in 1965 was only $66 for the 33% of the households engaged in this activity (USDA, p. 7). However, interest in home food production has increased sharply in recent years. Some 44% of all households had a vegetable or fruit garden in 1976 (Kaitz, p. 20).

Home production has remained an important source of food for many rural families and is for some the dominant food source. A survey of rural families in 1971 found the average family produced $124 of food at home per year at retail value. Some 60% of the families surveyed produced at least some food for home consumption with an average value of $206 per year for producing families. The value of home-produced food was as high as $1,868 for one family.

The role of home food production in satisfying rural family food needs has definite policy implications. The widely used Orshansky poverty index, which is based upon the minimum income a family needs to obtain an adequate diet, takes account of the amount of food households raise for themselves. The poverty threshold for farm families was set at 70% before 1969 and is currently set at 85% of the nonfarm threshold for each family type. This differential is based on the assumed cost savings from home-produced food. A federal technical committee in 1973 recommended that the farm-nonfarm distinction be dropped, however, arguing the questionable appropriateness of singling out income differences in this single factor alone (HEW, p. 90). Most welfare programs take no account of home food production. Even the food stamp program ignores the implications of home-produced food. Program participation is significantly lower in rural areas, though, and home food production may be a partial cause.

The traditional theory of consumer behavior is inadequate for the present analysis since home-produced food is a nonmarket commodity that has no explicit price and requires a large time input on the part of the household. For the latter reason, the opportunity cost of time of the family members and the productive efficiency of the household are important factors. Becker's household production model reformulation of conventional demand theory offers an appropriate analytical framework under these circumstances. Within the household production approach, this study estimates three specifications of the demand function for home-produced food using a 1971 cross-sectional data set for rural families. The equations are estimated with ordinary least squares, weighted least squares, and, finally, with Tobit analysis.

The Model

Becker's model consists of four elements: a utility function into which household-produced commodities enter, a household production function, a time constraint, and an income constraint (Becker, pp. 495–500). Dropping the household subscripts, assuming a single person household for simplicity, and following the derivation of Prochaska and Schrimper leads to the following demand function (p. 596):

$$(1)\quad Z_1 = f[(V + \hat{W}T),\ (\mathbf{P}_1\mathbf{a}_1 + \mathbf{t}_1\hat{W}),\ (\mathbf{P}_2\mathbf{a}_2 + \mathbf{t}_2\hat{W})],$$

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where Z_1 is the annual retail value of food produced for home consumption by the household; $V + \hat{W}T$ is the full income of the household: V is annual nonlabor income of the household, $\hat{W}$ is the potential wage rate of the household member, and T is total time available to the household member; $\mathbf{P}_1\mathbf{a}_1 + \mathbf{t}_1\hat{W}$ is the full price of Z_1: the sum of the market price ($\mathbf{P}_1\mathbf{a}_1$) and the nonmarket or time price ($\mathbf{t}_1\hat{W}$), where $\mathbf{P}_1$ is price vector of market inputs, $\mathbf{a}_1$ is a vector of input coefficients, and $\mathbf{t}_1$ is a vector of time inputs used to produce Z_1; $\mathbf{P}_2\mathbf{a}_2 + \mathbf{t}_2\hat{W}$ is the full price of the alternative market-purchased food.

In the specification of the demand function for use in cross-sectional analysis, the typical assumption that all households face essentially similar market prices ($\mathbf{P}_1$ and $\mathbf{P}_2$) had to be made. In addition, observations on household production efficiency ($\mathbf{a}_1$ and $\mathbf{a}_2$; $\mathbf{t}_1$ and $\mathbf{t}_2$) are not available. Due also to the limitations of our survey data, only the effect of the chief income earner's opportunity cost of time can be studied. The opportunity cost of time for each member of the family capable of performing home food production activities is potentially relevant.

Adding variables to account for differences in socioeconomic characteristics between households, the demand specification to be applied with cross-sectional data becomes (Prochaska and Schrimper, pp. 596–97)

$$(2)\quad Z_1 = A_0 + A_1V + A_2I + A_3\hat{W} + A_4FS + A_5SH + A_6FNF + e,$$

where the variables are: I is annual labor income from wages and salaries of the household, FS is family size, SH is sex of the household head, and FNF is residence status either farm or nonfarm. The equation is specified in a linear form.

In addition to equation (2), a second specification derived from an alternative conceptualization of the household allocation process is also estimated. This second formulation of the demand equation assumes a weakly separable utility function or a branch utility function in Strotz's more colorful words (Pollak and Strotz). So far the assumption has been made implicitly that the household simultaneously determines the amount of food to produce at home and total food consumption, as well as other allocations. However, the notion that households have a two-stage maximization process may be more realistic. The first allocation is among broad commodity groups. The second step entails the optimal allocation within each commodity group. Households decide first on their total food consumption level and then on the allocation among food sources, home-produced and market-purchased. The utility function is partitioned into separate subsets or branches, such as for food.

The empirical implication of this concept is that the demand equation for a commodity within a branch can be specified as a function of the prices of the goods in the branch and total expenditure on goods in the branch (Pollak, p. 426). The branch utility concept implies a demand function for home-produced food with the wage rate and total food consumption ($TVFC$) as explanatory variables.

A third specification adds $TVFC$ to the variables in equation (2) to correct more adequately for differences in demand that arise out of variations in family composition and differing preferences for food between families. The family size variable (FS) is inadequate because the age and sex of family members are not accounted for on an adult equivalent basis.

Equation (1) requires the assumption of constant returns to scale and the absence of joint production. Otherwise, the implicit commodity prices depend on the household's preferences as well as on its technology and the prices of market goods (Pollak and Wachter). Joint production occurs if the household members derive utility directly from the time they devote to home production as well as from the commodity output. Pollak and Wachter believe jointness is pervasive. However, working only with rural households should reduce this problem. Rural households are more likely to be home producing food for the commodities yielded rather than for the enjoyment of gardening as a leisure time activity. The latter is definitely an important factor in suburban gardening. When joint production or nonconstant returns to scale exist, Pollak and Wachter propose that demand for a commodity be considered a funtion of goods prices, the wage rate, and nonlabor income. The specification actually estimated in this analysis, equation (2), essentially agrees with their proposal. Therefore, if jointness or returns to scale are viewed as a significant problem, equation (1) and the following discussion of the effect of specific factors can be ignored with-

out negating the empirical results of this analysis.[1]

Certain a priori expectations based on theoretical considerations may be formed about the effect of the variables specified on home food production. The expected sign of the income variables cannot be predicted, though. Nonlabor and labor income are specified as separate variables on the expectation that their effects on home-produced food may be different. Nonlabor income should more nearly reflect a pure income effect. Changes in labor income may embody a price effect, since the wage rate of household members other than the household head cannot be held statistically constant. Besides wage rate increases, labor income may also rise if the number of hours of market work by household members increases. In this case the household time left for nonmarket activities is reduced. For these reasons, the relationship between Z_1 and I will probably be negative or, at the most, have a small positive effect.

Since the time intensity of the production process varies between commodities, a change in the opportunity cost of time has a relative price effect. For commodities, such as home-produced food, with a large time input factor, the $\mathbf{t}_1$ in equation (1), a rise in the wage rate will induce the household to consume less of that item. In particular, since $\mathbf{t}_1$ for home-produced food is greater than $\mathbf{t}_2$ for market-purchased food, the price of the former will rise relative to the latter with an increased wage rate. By using the wage rate as a measure of the relevant cost of time, we assume that at the margin time could be switched between home production and market work. This assumption is frequently violated and the relevant time cost to home production may be different than the market wage rate in these cases.[2]

Due to data limitations, a major drawback of this study is the failure to deal with the effect of the opportunity cost of time of household members other than the chief wage earner. This person will normally be the male household head. The chief wage earner is not necessarily the only family member to engage in food production. He may even have a zero time input into this activity in some cases.[3] As the chief wage earner withdraws time from home food production in response to an increased wage rate, other members may substitute more time into the activity. Across households, the chief wage earner's potential wage may be higher and yet other family members' time costs lower in one household than in another. Since the chief wage earner might perform few or no food production activities, the former household may engage in more home production than the latter one. For these reasons, the expected negative price effect of the wage rate may be nullified and not empirically verifiable, since only one wage rate is isolated and the opportunity cost of time of other family members is not specifically held constant.

Since the income variables are not on a per capita basis, the family size variable makes that correction. At a constant household income level, the income position of the family on a per person basis declines as family size increases. Therefore, the family size effect is related to the direction of the income effects. In addition, larger families will, of course, have greater food needs to satisfy than smaller ones.

Growing one's own food requires some physical activities for which a greater capacity might exist in a male-headed household. More important, a male head usually means a two adult family; women usually heading single adult families. The basic time constraint on household production activities is more severe for a single adult family, because of the lack of assistance in performing market work and household production activities.

Other factors being the same, farm households will demand more home-produced food than nonfarm rural households because of the availability of inputs and greater productive efficiency. Farm families are more likely to already have the land and equipment necessary for food production, lowering the effective price of these inputs. Raising their own food involves the use of job skills for farmers and may be part of the normal work routine. Because of greater productive efficiency, the

[1] In a recent paper, Reuben Gronau (pp. 35–36) remarks that he sees no reason to view the problem of household production activities directly yielding utility as more serious than problems of psychic income arising from market work. The latter, although not yet satisfactorily accounted for, has not impeded labor supply research.

[2] A time allocation decision is still required between the myriad possible nonmarket uses of one's time.

[3] A 1965 national survey indicated that a slightly greater proportion of men than women spend time growing food (27% compared to 25%, respectively) (Morgan, Sirageldin, Baerwaldt, p. 126). For rural areas, a rather old study (1931) revealed that 90% of farmers contributed help to the family garden. The husband spent a daily average of 12 minutes gardening, compared to 4.2 minutes for wives and 3.4 minutes for children (Studley, p. 19).

quantity of market inputs and production time needed to produce a unit of Z_1 should be lower. The coefficients $\mathbf{a}_1$ and $\mathbf{t}_1$ in equation (1) are smaller. The relative price of home-produced to market-purchased food is, therefore, lower to farm families.

Data

This analysis is based on 1971 survey data of 628 rural families in the forty-eight coterminous states.[4] In addition to a broad range of data concerning the economic and social characteristics of each household, detailed information was collected on the types and quantities of food produced by the household for its own consumption. This information was translated into a money value by multiplying quantities by local market prices.

Although wage rate information was not reported in the survey, data on weeks worked and the corresponding income received by the chief income earner were available for 299 of the sample households. An hourly wage rate was computed based on the assumption that the household's chief income earner worked full-time (forty hours) when employed. Because this procedure created serious measurement errors and a computed wage rate was obtainable for less than half of the total sample households, an indirect approach was used. A wage rate equation with education level (*EDH*) and age (*A*) as explanatory variables based on the subsample of 299 households was estimated:[5]

[4] This survey was originally conducted by Research Triangle Institute for USDA to develop an index of economic welfare for rural families. The data were generously made available to us by Francis Magrabi of the Agricultural Research Service, USDA.

[5] See Prochaska and Schrimper (p. 598) and Gronau (p. 27) for a similar approach to estimating a wage rate. The t statistics are given in parentheses for equation (3).

$$(3)\quad W = \underset{(.85)}{-1.940} - \underset{(.74)}{.144\,EDH} + \underset{(2.78)}{.024\,EDH^2} + \underset{(2.69)}{.244A} - \underset{(2.81)}{.003A^2}.$$

$$R^2 = .22$$

These parameter estimates were then used to calculate a potential or estimated wage ($\hat{W}$) for the household head for each sample household which is then used in the home-produced food demand equations. In addition to its other advantages, this approach also allows us to place a value on the time of an individual not employed in the market labor force.

Empirical Results

Table 1 presents the coefficients and t statistics for three regressions. Regression (1) gives the results for the specification given by equation (2) in the text. Regression (2) is the demand equation based on the branch utility function concept. Regression (3) includes the total value of food consumption (*TVFC*) to capture the influence of taste preferences for food and family conposition.

The regressions were all run first with ordinary least squares (OLS). However, the weighted regression results (WLS) are presented, because Bartlett's test indicated the presence of heteroscedasticity when four subsets were grouped according to farm/nonfarm and sex of family head (Kane, pp. 373–79). The variance in the error term, for example, is several times greater for male-headed, farm households than for female-headed, nonfarm households. The data series were, therefore, weighted by multiplying through by the inverse of the standard deviations of the respective group variances (Wonnacott and Wonnacott, pp. 133–35 and 323–24). The OLS re-

Table 1. The Demand for Home-Produced Food: Regression Results

Regression Number	Constant Term	V	I	$\hat{W}$	FS	SH	FNF	$TVFC$	R^2
1.	567.61 (9.51)	−.0031 (1.17)	−.0023 (2.03)	−5.89 (1.65)	12.70 (4.16)	−57.59 (4.26)	−207.69 (7.14)	—	.31
2.	566.77 (9.52)	—	—	−11.52 (3.44)	5.76 (1.63)	−44.52 (3.35)	−220.47 (7.66)	.019 (2.58)	.31
3.	539.58 (9.08)	−.0060 (2.24)	−.0044 (3.57)	−6.91 (1.95)	5.59 (1.60)	−45.20 (3.30)	−208.32 (7.25)	.0326 (4.03)	.32

Note: t statistics are in parentheses.

gression package was then run on this transformed data.

The coefficients of determination (the R^2's) are quite satisfactory for cross-sectional analysis, but a large part of the variation between families remains unexplained. All the coefficients in regression (1) are statistically different from zero at the 10% level except nonlabor income. The signs of the coefficients conform to expectations, in particular the negative price effect of the wage rate. And home-produced food appears to be an inferior commodity based on the negative signs of the income variables. The parameter signs are consistent across the three regressions, which should increase confidence in their accuracy.

In regression (2), total annual food consumption has been added and the two income variables dropped. All the coefficients are statistically significant at the 1% level except family size. In regression (3), the coefficients are all significant at the 10% level except family size. The (*FS*) variable is retained, because it contains useful information and its *t* statistic is just below the 10% significance level. Dropping family size had no appreciable effect on the remaining coefficients or their significance in either regression.

Based on regression (1) and evaluated at the mean values, the elasticity for labor income is $-.12$ and $-.09$ for nonlabor income. This negative elasticity should really be interpreted as describing home production as an inferior activity, rather than home-produced food necessarily being viewed as inferior by rural families. In terms of earned income, if the higher income depends on longer work hours, then the family will simply have less time remaining for household production activities. The wage rate produces a price elasticity of $-.19$. Holding other factors constant, increasing household size by one member would be associated on average with a \$12.70 increase in the value of home-produced food. For the binary variables, female-headed households consume \$58 less home-produced food on average than male-headed households. Farm-nonfarm is the variable which explains the largest proportion of the variation in home production between rural families. Farm households produce on average \$208 more of their own food than nonfarm households.

An additional complication was posed in the empirical analysis, since 40% of the households surveyed reported having no home food production. Since a negative value is impossible, the dependent variable has a lower limit of zero and a heavy concentration of observations at the limit. Under these circumstances, the assumptions of the multiple regression model are not realized. Tobin developed a hybrid of probit analysis and multiple regression for use in this situation. Tobit analysis takes account of both the probability of limit responses and the size of nonlimit responses (Tobin, p. 25). The explanatory variables affect both the number of households home-producing food and the quantities for those households with positive production.

Tobit analysis was applied to equation (2). Parameter estimates based on maximizing a likelihood function that takes into account the truncated distribution of the dependent variable are one of the components in Tobit analysis. For the specification in equation (2), the maximum likelihood solution (MLE) yielded estimated coefficients that were statistically significant at the 1% level for each variable. The expected value of home-produced food generated by Tobit analysis for a given set of values of the independent variables is equal to the product of the expected value based on the MLE regression times the probability of positive home production plus the product of the standard error of the equation times the density function of the normal distribution.[6] Arc elasticities at various levels were then calculated by relating the percentage change in the Tobit expected value of home-produced food to a percentage change in an explanatory variable.

Table 2 presents the elasticities generated by Tobit analysis calculated at the mean values, and at one-half and twice those values. In addition, Tobit analysis predicts that home production will increase by \$185.24 in going from a nonfarm to a farm household and by \$64.34 in going from a female to a male-headed household, all other factors remaining unchanged. The magnitude of the Tobit elasticities are related to the level at which they are evaluated, in part due to the change in the probability of positive home production over the range of the explanatory variables. In comparison, the elasticities based on the WLS regressions seem to understate substantially the responsiveness of home-produced food to changes in the specified variables. The responsiveness of home production appears to

[6] See Tobin, and Thraen, Hammond, and Buxton for a full explanation of the Tobit methodology.

Table 2. Tobit Elasticities Evaluated at Three Levels

	Elasticities at:		
Variable	One Half the Mean Values	Mean Values	Twice the Mean Values
Wage rate	−.16	−.35	−.79
Nonlabor income	−.06	−.13	−.28
Labor income	−.09	−.18	−.38
Family size	.17	.33	.58

Note: The mean values are wage rate = \$3.93, nonlabor income = \$1,599, labor income = \$6,414, family size = 3.37.

be underestimated if the effect of shifts by families in and out of this activity are ignored.

Conclusions

The most obvious shortcomings of this study relate to the specification of the time costs. Only the time costs of the chief income earner are introduced. Time is valued at the market wage rate. A potential or estimated wage return is used. These deficiencies are due to data limitations, and there is little hope of overcoming them in the foreseeable future with a better data set. Additionally, in going from equation (1) to an empirical specification, much of the rich subtlety of the household production model is lost. Finally, the single equation approach may be insufficient, given the seemingly interrelated nature of household allocation decisions.

In addition to a negative income effect, home-produced food is subject to a distinct price effect. Implications from this cross-sectional evidence can be inferred to the historical pattern. Because of the extreme multicollinearity of the major explanatory factors, the time-series data cannot be directly analyzed. By inference though, the secular decline in home production as a food source can be attributed not only to increasing urbanization and real incomes, but also to the rising value of time as market labor returns rose. Likewise, the upsurge in home production in the last five years can be partially attributed to the effects of the recent recession on real wages, producing both an income and a price effect. At the same time, market-purchased food prices were sharply rising and preferences may have shifted.

This study typifies the usefulness of extending economic inquiry into the study of behavior within the household. The greatest contribution of the household-production approach has been to reduce the amount of behavior that is considered inexplicable in terms of economic factors. The household production model yields a demand function for home-produced food which has greater explanatory powers and more fully utilizes economic theory than an ad hoc specification or traditional consumer theory. Less of the observed variation in household behavior must be left attributable to preference differences. If a fuller range of data were available on households, the explanatory power of the household production model could be even more richly utilized.

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Discussion

Robert T. Michael

Over the past decade there has been increasing effort by economists to measure and to understand determinants of productive activities which take place outside of formal markets. These efforts are partly motivated by an interest in modifying national income accounts and measures of real income to incorporate nonmarket production—studies by Tobin and Nordhaus, Sirageldin, and Kendrick are representative of these efforts. They are in part motivated by developments in economic theory which focus on the productive nature of nonmarket activities and the relevance of nonmarket time allocation. Becker's seminal essay (1965) on time allocation and its application to health (Grossman), fertility (Willis), and home production (Gronau) are representative of this work.

The three papers under discussion here add to the long list of studies of nonmarket time uses; I applaud the intentions of the authors in extending this analysis into additional nonmarket activities. (Unfortunately, my discussion could not include Evenson's paper as it was not distributed prior to the meeting.) There may still be a few skeptics who question the appropriateness of treating "health" as a home-produced commodity in which market goods such as physician services and drugs are used with nonmarket time in a productive activity that yields units of good health. But I doubt if anyone would argue that it is inappropriate to consider planting, caring for, and harvesting a vegetable garden as a productive activity, or inappropriate to view time spent in volunteer activities in schools, hospitals, or fire departments as a product-generating time use.

The amount of research on nonmarket production to date has, I think, provided convincing evidence that time allocation in the home and between home and market responds as theory suggests to changes in time value, level of income, and tax and subsidy incentives. We need no longer be agnostic about this point, but, rather, I think it appropriate to adopt as a maintained hypothesis that increases in time value cause substitution away from time-intensive (toward money-intensive) modes of nonmarket production and away from time-intensive commodities. Household behavior in example after example has been shown to be consistent with this theoretical model of behavior. Consequently, the contribution to be made by additional studies is not so much in "testing the model" as in providing quantitative estimates of response parameters in various circumstances.

Turning to the particulars of the Stinson paper, the household production function approach is used heuristically; no "model" is developed in the paper. As I see it, the first few pages tell us that time devoted to volunteer activity can be analyzed in a time-allocation framework and, in particular, the first order condition for optimal time use in volunteering is that at the margin the utility of such time must equal the utility of the opportunity cost of that time measured net of tax savings. That is surely correct as far as it goes. I think it is unfortunate that Stinson chose to "ignore" the "utility derived from the act of volunteering." On the basis of no evidence other than introspection, I would guess that peer pressure, satisfaction from socializing, social identity, or whatever one chooses to call it, is in the case of volunteering (as in the case of voting) a primary motivation.

Stinson's theoretical discussion makes no mention of recent work on the economics of charity or altruism and disregards the difficult issue of externalities related to volunteer activities. His discussion of a "community choice model" is especially troublesome. Even if we are willing to suppose an individual's decision to volunteer depends on sw (positively) and oc (negatively), the use of community averages of these two variables is highly unsatisfactory (see figure 1). To indicate why, suppose we scale these dollar shadow wages (sw) and dollar opportunity costs (oc) such that if $sw > oc$ the individual

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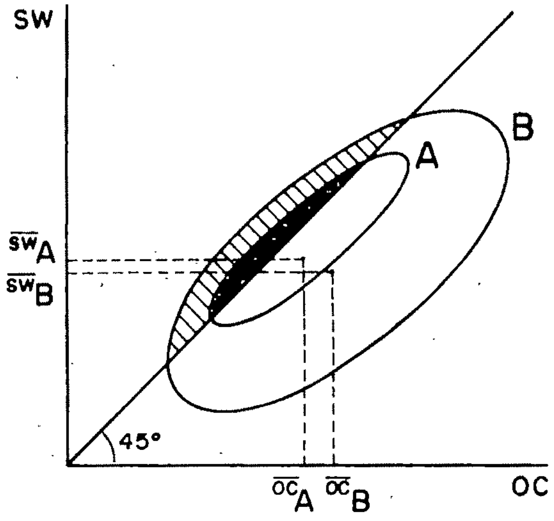

Figure 1. Community Choice Model

volunteers. Then suppose elipse *A* on the accompanying figure represents the joint distribution of these two values for individuals in community *A*. These individuals in the shaded area of the frequency distribution will volunteer (since for them $sw > oc$) and the other citizens will not. Community *B* has a higher mean *oc* and a lower mean *sw*, so Stinson would expect fewer volunteers in *B* on both accounts. But because of either (or both) a weaker positive covariance between *oc* and *sw* in community *B* or a larger variance in *oc* and *sw* in community *B*, it is not impossible for *B* to have many more volunteers than *A*.

Stinson eschews household time budget data. That, too, is an unfortunate decision. Time budget data do exist. Walker's data include volunteer time (Walker and Woods) and perhaps the University of Michigan's ISR time budget study or the twelve-country time use data reported in Szalai would have relevant information.

Regarding the empirical results with the community observations, Stinson's finding that the probability of a community having a paid fire department is greater the less residential the tax base seems an intuitively reasonable result. The finding that the probability is greater the smaller the fraction of the community's labor force that is self-employed is far less intuitive. Stinson suggests this negative effect reflects the larger "shadow wage" of the self-employed as their real property is greater, but one generally assumes that self-employed also have a relatively high opportunity cost of time. It is likely that communities with large fractions of self-employed are small towns with no large industry, and with relatively large variance in income (at least among the entrepreneurs over time). So the interpretation is far from clear. While the positive income and size effects make sense, one suspects that the strange positive effect of the variable TCSUB reflects the availability of neighborhood fire departments—the externalities issue reappearing at a higher level of aggregation.

Perhaps due as much to style as content, I found the paper by Kinnucan and Sexauer more informative. The major deficiency in this paper is one noted frequently by the authors—lack of information about time use or time value for family members other than the family head. Many of the qualitative results from the regressions on these 600 rural families are what one might expect:[1] home-produced or home-grown food is less among nonfarm families and among those with higher nonwage income, with heads who worked more hours or who had higher wage rates, with smaller families, or with a female head. Of course, the observed effects of the wage and labor income variables confound the heads' and other family members' efforts.

My principal comment on this paper is that, fortunately, better data now exist. The recently available Bureau of Labor Statistics 1972–73 Consumer Expenditure Survey "Detailed Public Use Tape" contains information on the age, sex, employment status and weeks worked of each family member and such detail as "the value of home-produced food for canning and freezing," the "value of home-produced food eaten fresh," and such related expenditure items as "bulk food purchases for canning and freezing," "fertilizer and pesticides," etc. This survey of some 19,000 households with a relatively complete set of demographic characteristics should provide the authors with an excellent data source for further study.

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Discussion

Barbara S. Zoloth

My comments begin with Stinson's paper on voluntary fire protection, and most of my discussion will focus on that analysis. I will conclude with a few comments on the Kinnucan-Sexauer analysis of the demand for home-produced food.

The paper by Stinson is an appealing extension of Becker's time-allocation model. The use of volunteers to staff services—whether or not they are collectively consumed—has not been subjected to much economic analysis. In addition to general problems of measurement, a major reason for this has no doubt been lack of useful and reliable data sources. One particular measurement problem derives from the presumption that volunteer work must provide direct utility to the worker, since economic models generally preclude altruism. Stinson has neatly worked his way around a need to specify or measure the utility value of volunteer work by dealing only with collectively consumed and taxpayer-financed commodities. He is thereby able to identify a direct pecuniary return to the individual volunteer in the form of reduced taxes. This, of course, creates a free rider problem and is based on the implicit assumption that an individual's volunteered time would, if withdrawn, be replaced by a paid worker rather than by another volunteer. Furthermore, this latter assumption may well depend critically on the size of the community, being more reasonable the smaller the pool of potential volunteer workers. Nevertheless, this approach is clever and, most importantly, leads to some interesting and testable hypotheses.

Before discussing the empirical results, I will deal with some issues raised by Stinson's discussion of the theoretical model. He first presents an algebraic and general version of the time-allocation decision faced by a utility-maximizing individual. This model incorporates volunteer work in three ways: (*a*) as a direct argument in the utility function; (*b*) as an explicit part of the time-use constraint; and (*c*) as an indirect source of money income via tax savings, with the marginal value of these tax savings being a declining function of volunteered time. The first-order conditions are reasonably straightforward, as is Stinson's interpretation of them. This discussion is followed by a graphical presentation of the individual's allocation of time between work, leisure, and volunteer time.

For simplicity, Stinson treats all leisure time as homogenous and essentially ignores the household production function by replacing it, in the utility function, by its arguments. This is legitimate if a fixed-coefficients production function is assumed, as in Becker's original analysis. It might be easier, in this case, if the production function were left out altogether, letting both leisure and purchased goods directly enter the utility function to begin with. Since this analysis is not directly concerned with the equilibrium levels of either of these two types of commodities, there is no real need for an explicit production function. In any event, either the absence of a production function or the assumption of fixed coefficients is necessary if money income is to be used on one of the axes and time on the other in the indifference-map diagram.

The graphical presentation is made somewhat confusing by some assumptions that are implicitly made but not explicitly stated. Two indifference-map diagrams are presented, the first representing no constraints on the number of hours that an individual can work for wages and the second more realistically incorporating an upper limit on this number of hours. In moving from figure 1 to figure 2, however, the depicted relationship between the explicit money wage and the shadow wage for volunteer work changes. In figure 1, a range is shown over which the shadow wage is greater than the money wage, and this range is correctly represented as the lower right hand portion of the budget constraint. If an individual can work an umlimited number of hours for money wages, then that person will engage in volunteer work only if there exists some

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amount of volunteer time for which its shadow wage exceeds the potential money wage. Any amount of time that is worked beyond the level at which the shadow wage equals the money wage will be spent working for money wages. If there is no level of volunteer time at which its shadow wage is greater than the money wage, all nonleisure time will be spent in paid employment.

In figure 2, where a limit on the number of paid hours is imposed, Stinson now implicitly assumes that the shadow wage for volunteer time is nowhere greater than the money wage rate. There is no reason why this need be true in general, and no apparent reason why adding a constraint on hours worked should make it so. Furthermore, there is no reason why the slope of *DB* (the shadow wage of volunteer time) need equal the slope of *AB* (the money wage) at point *B*. In fact, the existence of a constraint on hours worked by itself means that the budget constraint will not be a smooth curve between points *A* and *B*. Actually, the particular type of volunteer work that Stinson analyzes—fire fighting—is also constrained in numbers of hours, since, once a person volunteers his or her services as a fire fighter, attendance is mandatory at all fires.

An alternative interpretation of figure 2 is that a lower limit (which is equal to the upper limit) has been placed on hours worked. This would explain why the money wage portion of the budget constraint is to the right of the volunteer portion (although not why their slopes are equal at point *B*), but it is not a particularly appealing assumption.

At best, this confusion hides the effects on volunteered time of limiting the number of hours worked. It does not, however, change Stinson's conclusion that, with this constraint, the effect of a change in the money wage rate on volunteer time is no longer unambiguous. It will depend on the shape of the indifference curves and, in particular, on the nature of the income effect. It seems reasonable to suspect, for example, that some sorts of volunteer work may be an inferior good, even relative to the shadow wage for that volunteer activity. However, since we are talking about a choice between three alternative uses of time (leisure, work, and volunteer time) in two dimensions, and since volunteer time is likely to be a direct argument in the utility function, it is difficult to visualize the possibilities.

Stinson also suggests, quite reasonably, that a person's part-time employment wage rate would be less than the full-time rate. He claims that an increase in the part-time rate will change volunteer time only if it becomes greater than the shadow wage. He further asserts that there will be a one-to-one substitution between hours worked and hours volunteered. I have been unable to verify either of these results graphically. Furthermore, it might be more realistic to consider an overtime wage rate rather than a part-time wage rate for hours worked beyond the constrained amount.

The empirical results in Stinson's paper are intriguing and enlightening, and I have no real criticisms of them. His choice of proxies for the variables of interest are reasonable and inventive, and his interpretations of the results are sensible and appropriate. As a suggestion for further inquiry, I would be interested in additional explanation of the differences between the results yielded by the probit analysis and by the Tobit analysis. Also, a further exploration of the hypothesis that Stinson rejects—namely, that population size and income differences alone explain difference in communities' volunteer behavior—would be helpful. Do, for example, the other coefficients need to be zero for this hypothesis to be true? Are the behavioral assumptions behind this hypothesis really much different from those implicit in the Becker model?

I have focused particularly on Stinson's paper here not so much because I felt it deserved more criticism as because it deals with a little explored but highly important realm of economic behavior. Stinson's foray into this area is highly laudable and I strongly encourage further study of voluntarism by any interested researchers.

The paper by Kinnucan and Sexauer deals more explicitly with intra-household production activity and is an extremely well done study of the demand for home-produced food. I find no major points of criticism and make here only one technical suggestion which, in fact, applies to both papers. Nonlinear estimation techniques like probit and Tobit yield estimated marginal effects that depend on the point of evaluation. It is standard procedure and very appropriate to evaluate the independent variables at their means. I would suggest that it is equally appropriate to consider values that are one or more standard deviations on either side of the mean. This would make more sense that using one-half and twice the mean values as Kinnucan and Sexauer do, or using a

10% increase from the mean as Stinson does. Using standard deviations would make the distances travelled from the mean considerably less sensitive to the mean value itself.

In addition to applying economic theory to important aspects of individual and household behavior, both of these papers suggest several intriguing extensions of the directions they have taken. I have learned a great deal from reading these papers and I encourage the authors in their further pursuits of these areas of research.

Publications

Books Reviewed

Note from the Book Review Editor

The entire book review section of the current issue has been devoted to volume 1 of *A Survey of Agricultural Economics Literature*. Much effort has gone into the preparation of this volume, not only by the authors of individual chapters, but also by those who set the scope for the work, prepared outlines for various sections, and reviewed drafts of manuscripts. Yet there has been no appraisal of the volume as a whole. It was thought that the *Journal* might be able to make a unique contribution in this regard and also bring more visibility to a project which has concerned such substantial professional resources. Accordingly, three members of the profession have been asked to comment on this volume in its entirety.

Obviously volumes 2 and 3 of this series are potential candidates for similar treatment by the *Journal*. If there are suggestions from the readership to proceed with these in a similar or different fashion, the Book Review Editor would like to receive them.

Herbert H. Stoevener

Martin, Lee R., ed. *A Survey of Agricultural Economics Literature*, Vol. 1. Minneapolis: University of Minnesota Press, 1977, 540 pp., $25.00. $18.00 to AAEA members through 31 May 1979.

Here is the first of a new three-volume set of reviews commissioned by the American Agricultural Economics Association, designed to cover the professional literature in "traditional" fields of agricultural economics from the 1940s to the 1970s. To grapple with this formidable task, ten seasoned researchers wrote seven lengthy articles, each with its own bibliography—some 2,300 citations in all. Their emphasis is almost exclusively on U.S. research and writing.

The first chapter, covering work in farm management and production economics, was written by Harald Jensen. Next, Ben French surveys the research on productive efficiency in agricultural marketing. George Brandow follows with an examination of the literature on agricultural policy for commercial agriculture. Post-war trade policy work relating to agricultural products is evaluated by D. Gale Johnson. The final three papers in this volume are jointly authored. William Tomek and Kenneth Robinson discuss the work in agricultural price analysis and outlook. Agricultural finance and capital markets research is covered by John Brake and Emanuel Melichar. Finally, Willis Peterson and Yujiro Hayami examine the literature on technical change in agriculture.

Each chapter features a short foreword by its author(s), the text of the review, and then a bibliography of literature. Editor Lee Martin kicks off the entire volume with a general introduction explaining the origins of this particular project and identifying some related literature reviews published elsewhere.

On the physical side, the book is well laid out, cleanly edited, and handsomely published. It seems designed to withstand hard and repeated use. This quality may be significant since there is no index to guide the reader. However, the table of contents, collected chapter by chapter at the beginning, is admirably detailed. In the absence of a topical index, it will be a distinct boon to browsers and searchers alike.

Unless they do it piecemeal over several years,, few people will read this volume in its entirety. Consequently, readers may not come to appreciate a quite singular feature of this collection. It is the markedly different way each of the authors has chosen to complete what one might consider offhandedly as a fairly routine if intimidating job—a review of the professional literature in one's own field of study. Some chapters, for example, are mainly detailed chronicles of the works and writings of a generation of researchers. Others are highly individual essays liberally sprinkled with citations.

In his review of farm management and production economics, Harald Jensen gives us a detached and clinical view of a field experiencing substantial intellectual and methodological ferment. The split between practitioners of "farm management" (practical, problem-solving) and "production economics" (rigorous, research-oriented) is etched as the conferences, projects, and literature of the 1950s and 1960s evolved. Jensen reminds us how crucially important to the research in this field and the debates within it was the joint development of linear programming (activity analysis) and electronic computers. The powerful influence and leadership of Earl O. Heady throughout this entire era is not minimized either.

Woven throughout Jensen's chapter is an epistemological theme. How does one identify the bounds of a scientific field of inquiry? Is there an "identity crisis" among professionals in farm management and production economics? Where does the future of this field lie, and who will be its clientele? The views of numerous leaders as well as Jensen's own on these matters are marshalled and summarized in addition to the surveying of research-oriented literature.

Of all seven chapters in the book, Ben French's survey of productive efficiency in agricultural marketing is by far the most specifically focused and

clearly circumscribed. It is basically a review of the theory and available empirical studies of plant costs and efficiency. Most of the chapter has to do with the micro analysis of plant operations, but literature on plant location and efficient organization over space also is surveyed. It is a straightforward job of organizing and cataloging this work generally along functional lines.

A herculean, eight-page, ninety-eight-study tabulation of findings about economies of scale in agricultural marketing plants is presented to show the pervasiveness of this phenomenon in empirical work. French easily wins the jackpot for most literature cited in volume 1. His 763 items are more than double those of his nearest rivals. And they are carefully organized by functional and commodity categories—a bonanza for both fledgling and veteran researchers.

French philosophizes rather little with us about his field of study. However, at the end he observes that marketing efficiency, as construed in this survey, may no longer be considered a distinct area of study but as part of the broader framework of research problems in agricultural marketing. We can agree.

In his chapter dealing with commercial farm policy, George Brandow has given us one of the strongest articles in this volume. It is an elegant interpretative essay about how agricultural economists learned to view the "farm problem" after World War II. It is about how public policy both paralleled and clashed with those views as it unfolded up to the 1970s. And it is about how economists have set out to analyze large and small chunks of the farm policy puzzle and what they have learned.

Brandow's work is not a simple listing of people and projects. In polished and balanced prose, Brandow carries the reader through the evolution of problem perception and policy analysis, providing a solid literature review along the way. This paper ought to be required reading in any course or seminar in modern agricultural policy.

Of course, all of the "traditional" fields covered in this volume overlap and blend into one another. The trade and trade policy field, surveyed by D. Gale Johnson, is no exception. It is, in my view, the least clearly defined area to be singled out for treatment in this book. Delineating this field from agricultural policy, the economics of development and growth, agricultural marketing, and agricultural demand and price analysis is not easy. Johnson reflects this problem in his chapter foreword by noting that his objective is to be "selective and illustrative rather than exhaustive" (p. 294).

As a result, Johnson's article and bibliography are short in comparison with most of the others. His general thrust is, first, to discuss policy conflicts between domestic programs and trade goals mainly from the U.S. perspective and to document them with some relevant literature. Then follows a section on the analysis and estimation of trade policy effects as they have emerged in the literature. Here the material surveyed spans a wide horizon, from studies of the effects of P.L. 480 shipments on the recipient countries to estimates of the economic impact of Great Britain's joining the European Common Market. This chapter closes with Johnson's views of future research directions in agricultural trade analysis. These involve work on continuing unresolved issues and some newer ones such as trade with the Soviets. Separate bibliographies of the U.S. Department of Agriculture's supply-demand studies for numerous foreign nations and USAID's demand studies are appended to Johnson's general reference list.

For survey purposes, Tomek and Robinson define agricultural price analysis as "the study of agricultural product and input prices over time, space, form or quality, and market levels" (p. 328). The literature encompassed by this rubric is wide and deep. Yet, the authors do a good, workmanlike job of sorting it out and organizing it. In fact, an especially strong feature of their chapter is its organization, mainly along functional lines suggested by economic theory. It may be that the topics and literature of price analysis lend themselves neatly to classification. If so, Tomek and Robinson have seized the opportunity.

The price analysis survey itself focuses on the postwar application of approaches and "ideas" rather than upon research methodology and technique. This wider view is wise since volume 2 emphasizes quantitative techniques in agricultural economics research.

Rereading this chapter, I came to realize that its very first section plunges the reader quite abruptly into the single equation versus simultaneous equation literature. A few introductory paragraphs to set the tone and objectives of the chapter, as well as to locate agricultural price analysis in the general scheme of things, would have been helpful. But this is a strong chapter and deserves to be widely consulted.

Of the "traditional" fields covered in volume 1, this reviewer is least familiar with the agricultural finance and capital markets literature. Brake and Melichar have assembled 300 citations and organized their commentary on them in what seems to be a traditional, more-or-less chronological pattern by major subject categories. This chapter is a review of literature in the strict sense. Not much of the general philosophy or opinion of the authors emerges until the last section where some new directions for research are spelled out. In a closing observation, Brake and Melichar criticize their colleagues for failure to build new research on previously-laid foundations and for some needless duplications of effort. Their work in this volume should help offset both problems.

The final chapter by Peterson and Hayami is a well-written essay on the economics of technical

change and diffusion in agriculture. It is, in the main, a nontechnical summary of the recent theoretical literature in this field with empirical illustrations scattered along the way. If you do not know how technical change has been incorporated into economic analysis, you can learn almost all you need to know from this fairly short chapter without calculus or algebra. For instance, I believe I can now distinguish between "embodied" and "disembodied" technical change, a previously hopeless struggle.

What general comments can a book reviewer make about a book of reviews? For one thing, he can speak about omissions. The chapter on the organization and performance of agricultural markets, now scheduled for volume 3, clearly belongs in volume 1. It is a "traditional" field of study and should have been included here. A reviewer can speak about the book's general quality of writing. Some is wooden and dull, but much is surprisingly lively with a sense of intellectual excitement and zest. The expertise and experience of the writers is always evident. A reviewer can consider who might usefully acquire the book. This volume should be in any library, public or private, which serves people doing research in agricultural economics. Agricultural economists without access to such a library surely ought to consider its acquisition. In addition many serious researchers will certainly wish to have personal copies readily at hand.

Is the benefit/cost ratio of this literature survey project greater than 1.0? Who can say? But I for one am glad that the AAEA and editor Lee Martin decided to do the job. Perhaps we should all read volume 2 on quantitative methods to see if benefit/cost analysis is covered.

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A Survey of Agricultural Economics Literature, Vol. 1

A review is likely to reveal as much of the reviewer as of the reviewed. This is true of the authors of this volume, despite the moderating effects of numerous associates who outlined and others who reviewed the manuscripts from which this volume was prepared. The high quality of the results can be ascribed to the high quality of the authors and of their associates, "participant observers" in the literature surveyed.

Volume 1 is characterized by editor Lee R. Martin as traditional fields of agricultural economics. H. C. Taylor, in 1952, identified agricultural economics to be comprised of farm management, marketing farm products, land economics, farm labor and wage rates, and farm finance. Farm management is well represented in volume 1, teamed with production economics by Jensen and with finance, by J. Brake and E. Melichar, who also treat other aspects of agricultural finance extensively. Thus farm finance, too, is well represented. Marketing farm products is treated rather curiously by French, who surveys the literature on production problems of firms in farm commodity markets, and by W. Tomek and K. Robinson, who survey the literature on price analysis and outlook.

Land economics disappears as a separate topic, though pieces are recognizable in Jensen's review (especially in literature relating to agricultural adjustments and aggregative analysis) and in Brake and Melichar's (particularly in the literature dealing with land prices). More will likely follow in volume 3 of the *Survey, Economics of Welfare, Development and Natural Resources*. However, one looks in vain for literature on land tenure and its role in either management, finance, or policy. Farm labor and wage rates are mentioned briefly by Tomek and Robinson, in a market context. Jensen reports on the search for labor coefficients required in modeling farms. Little is reported on managerial aspects of farm labor. A wider scope of literature might have revealed more. However, few would argue with the decision to set aside farm labor as a "traditional field," given developments of the past twenty-five years. What of twenty-five years hence?

Nor would many argue against including public policy as a traditional field, Taylor to the contrary. G. Brandow surveys the literature in price and income policy; D. Gale Johnson, literature concerned with trade in farm exports. Some might find it strange that developmental aspects of public policy are not given more attention. However, an important part of development is covered by W. Peterson and Y. Hayami who review literature dealing with technical change in agriculture. Taylor, in 1952, would likely have been surprised to find technical change highlighted as a "traditional field" of agricultural economics. All classification systems have large degrees of arbitrariness, but it might have seemed a bit less curious, had technical change been placed in the broader context of developmental economics, to which our profession has made large and useful contributions in the review period, 1940s to 1970s.

The literature surveyed is produced largely by academic and government researchers. The survey is designed for an audience in the same population. We are talking largely to ourselves in this volume. But so we were also in much of the reviewed literature. The postwar period has been one of considerable scholastic achievement. Our profession has been transformed by new methods, for example, operations research methods, and by improved research capacity, for example, computer hardware and software. But volume 1 of the *Survey* amply supports those critics who indict agricultural economists for failing to speak to our clientele. The users of our research results are left to glean what they can by eavesdropping on the dialogue among the professionals. At a minimum, such an orienta-

tion places a heavy communication burden on our extension brethren.

More fundamentally, the reader is left uneasy about the utility of the profession. Nearly all the authors felt it necessary to lead into the period under review with brief summaries of work done in years preceding World War II. It is evident that our predecessors were more closely associated than we are with decision makers using the research results. This linkage likely accounts for the recognition and growth of agricultural economics in postwar years. Perhaps the growth itself accounts in part for the higher degree of "internal communication" which has evolved. New and more heterogenous entrants had to be accommodated, as well as new research methods. We now have a much larger and more varied professional bureaucracy to be "fed" than did our predecessors, even within the "heartland" of the profession. Maybe as many now as among our predecessors are in direct communication with decision makers—maybe more. But their literature is not the part of the literature under review. This is understandable, though many will find it deplorable. Much of their literature is unpublished. Large parts that are published are scattered, in-house, and are hardly retrievable. Finally, there is a strong presumption that the literature under review here is fundamental to that which is more directly associated with decision making and policy choices.

In two of the articles production economics is the essential theme. In the first article, Jensen reviews "Farm Management and Production Economics," outlining the impact of production economics on farm management. In the second article, French reviews "The Analysis of Production Efficiency in Agricultural Marketing. . . ." His concern is with literature in which production economics is applied to firms in farm product markets.

Jensen spotlights Earl O. Heady as the prime mover in farm management research in this period. Few would argue. He casts Glenn Johnson in the role of conscience, pointing to Johnson's arguments on the dangers associated with choosing problems on a disciplinary basis instead of using a problem point of departure. Jensen finds it useful to include a section on regional research developments. Some will detect a "Midwest bias" as we revisit the Black Duck Conference once more. It is easy to find items of considerable significance that have been ignored: examples, Jean Marc Boussard and Michele Petit, "Representation of Farmers' Behavior Under Uncertainty with a Focus Loss Constraint," *Journal of Farm Economics,* 49 (1967):869–80; George Irwin, "A Comparative Review of Some Growth Models," *Agricultural Economics Research,* 20 (1968):82–100. No reference is made to research associated with farm planning as developed by the Farmers Home Administration and the Soil Conservation Service. Some may think the treatment given closely associated extension activities to be rather slight, especially in the development of computer-assisted planning methods. Other topics are treated lightly or not at all: e.g., portfolio theory, capital budgeting, expected utility theory, and lexicographical utility theory. Comments on methodological literature are confined largely to linear programming, with brief references to dynamic programming and to simulation methods. Within these limits we are given an interesting history of intellectual developments in this rapidly changing part of agricultural economics since the mid-1940s.

French produced an excellent review of the literature which brought the economics of farm-related market firms into prominence in the post-war period. No personalities were highlighted. Yet the dominance of the University of California shows through. The reader is well advised to consult French on the technical aspects of production economics. He provides a useful discussion of specification and measurement problems and of economic-engineering research as related to firms in farm-related markets. The article is flawed somewhat by attempts to distinguish production economics as applied to "marketing" firms, on the one hand, and to "producing" firms, on the other. Yet it reflects with considerable fidelity the ambivalence of literature in this field. To those outside the field, it seems apparent that there has been something of an identity problem over the past couple decades. Perhaps it is to French's credit that he spares the reader the agonizing that might have absorbed a considerable part of his article, in favor of a straightforward review of the literature as it exists.

Brandow's review of "Policy of Commercial Agriculture" focused on interventions of the federal government in product markets of farmers: in price supports, export subsidies, output control, forward prices, income maintenance, bargaining assistance, and marketing orders. In so choosing the literature to review, he reflects rather faithfully the weights given by the profession to these topics in what commonly is recognized as "policy," giving short shrift to policies with respect to state and local fiscal needs, federal fiscal-monetary alternatives, farm credit, trade, food systems, input markets (including land), conservation and water resource development, rural community development, rural labor, and rural education. Some of these latter topics are, of course, treated elsewhere either in this volume (for example, trade) or other volumes (for example, conservation and water resource development). However, the economic welfare of farmers and others is affected by all the policy areas, and the linkage of price and income policy with many of the other topics are important. In sum, we have here a competent review of price and income policy, linking that policy with events of the pre- and postwar periods. The reader is left to link price and income policy with other areas of public policy as related to agriculture and food problems.

In a concise review of "Postwar Policies Relating to Trade in Agricultural Products," D. Gale

Johnson provides a useful summary of the principal issues in postwar trade policy with respect to export markets of agricultural products. They center on the tensions created by a "liberal trade policy that would guide farm production in the directions implied by the principle of comparative advantage and the needs of the domestic farm programs that require substantial interferences with international trade" (p. 295). Current headlines remind us that the problem persists. In his review, Johnson includes a brief statement on farm and trade policies of other countries, with special emphasis on developed countries, though he also includes literature dealing with the effects of PL 480 shipments on recipient countries. Johnson provides an especially interesting agenda for future research in this increasingly important area, calling for estimates on the effects of trade restrictions, adjustment problems created by freer trade (along with a search for relevant kinds of assistance for those who are affected adversely), the effects of price support policies on trade and price stability in international markets, and how to improve our ability to trade effectively with centrally planned economies. He suggests the interesting hypothesis that "the price behavior of internationally traded farm products since late 1972 may have been due largely to trade interferences and not primarily to shortfalls in production or to increased demand" (p. —), citing work of his own that lends support for the hypothesis, as well as arguments to the contrary.

Tomek and Robinson survey the postwar literature in "Agricultural Price Analysis and Outlook." It is a competent summary of the important literature dealing with supply and demand aspects of farm commodity markets as well as with price outlook. They place considerably less emphasis on prices of farm inputs and on farm-nonfarm price relationships. In this they reflect in their article the weights given these various topics by agricultural economists during this period. Some readers may be disappointed to find little attention given to effects of market power on price determination, to the effects of inter-firm coordination on the importance of prices, and to the new factors in farm production markets (for example, export markets), new methods (for example, sequential modelling), or new problems (for example, tests for simultaneity in market determination of prices). Such omissions would have been less important had there been another article dealing specifically with the exchange aspects of marketing. Perhaps the topics were not targeted in the outline developed for this article. Perhaps it is a weakness of the literature itself. In any event there appear to be gaps in the marketing literature included in the survey, even though it may not be proper to assign the blame to the authors, either Tomek and Robinson or French.

Brake and Melichar survey the literature in "Agricultural Finance and Capital Markets," reflecting well the literature available from the profession over the past twenty-five years. The dominant topics are financial management (by which is meant farm financial management) and financial markets (institutional and functional aspects) related to farming. They organize the literature under capital formation and accumulation, trends in capital and resource organization, capital flows and their financing, credit institutions and policies, and capital markets and financial intermediaries. Overlaps lead to a bit of repetitiveness as well as to some choppiness in the flow of the article. However, they summarize much of what has been accomplished in the profession. Again the omissions are significant. Micro methodology (e.g., capital budgeting, operations research, and portfolio theory) receives little attention while macro methodology (e.g., flow-of-funds modeling) receives relatively much. Little is included on financial problems of firms in farm-related markets, in financial aspects of international trade, in problems of financing rural development, and financial aspects of public policy. While the profession may have done little on these problems, it might have been useful had the areas been recognized, if only in the concluding section on "suggestions for future research."

Peterson and Hayami conclude the volume with "Technical Change in Agriculture," a subject perhaps less recognized as "traditional," providing us with a well-organized review of the profession's literature in this important area. Technical change in this period may well have been the most important of the many factors influencing the welfare of farmers and of those related to farmers through markets and nonmarket institutions. The literature reviewed is highly relevant and the review competent. Both appear somewhat weak on the distributional effects of technical change. Nor is much attention given to the problem of criteria by which to allocate research resources among alternatives. What are the consequences of our present procedures (largely peer review)? How would the effects differ if some form of capital budgeting (i.e., cost-benefit) procedure were to be made operational? What could expected utility theory contribute if we made decisions on the basis of deduced value of added information? As a matter of fact, what if the customers were asked? Whatever the aggregative benefits from technical change, many adjustment problems have been generated for innovators who were not asked! Such items might well have been expected in a research agenda, missing in this article.

In such a survey, it is easy to be critical. Despite the massive assembly of literature citations, even in the narrow scope identified, it is easy to find omission. Yet the profession is indebted to the editor, Lee Martin, to the authors in this volume, and to the numerous professionals who contributed with outlines and critical reviews. Those directly involved with teaching and research can

hardly afford not to have a personal copy. Others who work closely with agricultural economists in decision making or policy will find it useful in explaining the character and evolution of important parts of the field. Still others will find many events of past decades placed in an interesting historical context. Despite its inward look agricultural economics affects as well as is affected by economic events of agriculture.

C. B. Baker
University of Illinois

Reference

Taylor, H.C. *The Story of Agricultural Economics.* Ames: Iowa State College Press, 1952.

A Survey of Agricultural Economics Literature, Vol. 1

If the association has ever undertaken a more useful project than this one of sponsoring, preparing, and publishing this three-volume survey of agricultural economics literature, it is not apparent what it is. The good that will come from this effort is incalculable. C. E. Bishop, president in 1968, must be congratulated for initiating investigation of the need for such a survey. The committee he appointed must be given the credit for correctly perceiving the value of the survey and giving it its broad shape.

The survey will be valuable to those within the profession who will find in one place a tremendous reservoir of literature citations in their chosen field. It will also be most useful to those without the profession who want to get some idea of the substantive content and methods utilized in modern agricultural economics.

The professional input into the project has been quite remarkable—from that of the original committee who tentatively identified the fields to those who prepared outlines and, thus, wrestled with the problems of coverage, those who undertook the major job of preparing and writing the various papers, and, finally, those who critiqued and evaluated the final product. Given this prodigious effort and finely tuned organization, it is no accident that the product is so very, very good.

Of course, with so many contributing at so many levels, it is difficult for the reviewer to ascribe definitive responsibility both in giving credit for the many "right" decisions and blame for the few questionable ones. It is likely that no single individual could have had all of his preferences satisfied—even the writers of each chapter—since topics were broadly defined by the committee and each piece was formally reviewed by several "authorities" chosen for their expertise and standing in the profession. Such reviews would have to be taken seriously by the chapter authors, and compromises were probably required.

The committee must have struggled hard with the difficult issue of defining the field and dividing it into coherent subareas around which the individual surveys could be developed.

In this connection, I would take issue with one of the decisions on choice of placement of topics among the three volumes. Volume 1, being reviewed here, is titled *Traditional Fields of Agricultural Economics, 1940's to 1970's.* All seven chapter topics in this volume obviously belong. But what about "Natural Resources" or its older name, "Land Economics." This area has a long and distinguished history as a traditional field of agricultural economics. What could be the rationale for placing it in the third volume with welfare and development topics? Also, in terms of numbers of professionals working in this area and the variety of problems considered in the economics of natural resources, a single chapter seems to me to understate its relative importance despite the assignment of the very able group who will be responsible for writing it.

Let us move from this negative note to a discussion of the assigned volume 1. The individual parts are of two types or run the gamut in between (*a*) reasonably complete compilations of citations covering a broad field that will serve as a handy reference for future and more probing search and analysis, and (*b*) deep and analytical assessments of the most significant literature of a more circumscribed field. In some conditions the first type will be most valuable and, in others, the second is what is needed. The researcher undertaking a study in an area new to him would pay a high price if the important literature were missed in his search; thus, a survey that was broad and exhaustive would be most valuable. On the other hand, a graduate student attempting to master a given field would value more highly a survey that identified and discussed only the more critical pieces but evaluated them in terms of their substantive content and validity of their principal arguments. Obviously, in a given number of pages, a trade-off exists between coverage and depth. The surveys in this volume strikingly illustrate this trade-off in their dissimilarity. Thus, it is appropriate to ask: (*a*) what literature is being reviewed, (*b*) how thorough is the coverage of the substance of the literature cited, and (*c*) what time period is spanned by the survey. Some data on these questions are contained in the table. I will now discuss each of the parts in turn in the context of these questions.

Nowhere in the entire volume are the contrasts alluded to above greater than in the first two parts. In the opening article, Harald Jensen surveys the broad field of farm management and production economics. This area has dominated agricultural

Table 1. Period Covered by Review Source and Time Period Covered by Literature Citations

Part	Title	Period covered	Citations before 1960	Citations from *AJAE*
			%	
I	Farm Management and Production Economics	1946–70[a]	56	78
II	Analysis of Productive Efficiency in Agricultural Marketing: Models, Methods, and Programs	1937–75	40	8
III	Policy for Commercial Agriculture	1945–71[b]	36	29
IV	Postwar Policies Relating to Trade in Agricultural Products	1962–75	0	11
V	Agricultural Price Analysis and Outlook	1946–73[c]	28	37
VI	Agricultural Finance and Capital Markets	1945–75[c]	22	22
VII	Technical Change in Agriculture	1945–74[d]	26	28

[a] References actually covered period from 1926–73.
[b] References actually covered period from 1937–72.
[c] References actually covered period from 1914–75.
[d] References actually covered period from 1933–74.

economics as a whole as the field was developing. Jensen's primary literature resource is the *American Journal of Agricultural Economics* (78% of his citations came from the *AJAE*). The dating of the citations is also significant (56% before 1960). Now, it may be true that a larger proportion of the significant literature of farm management and production and economics was published in the *Journal* than was the case for the other fields surveyed, but I do not believe that the disparities could be so great as the numbers in the table suggest. Either Jensen's survey neglected the literature outside the *Journal* or the other writers neglected the *Journal* or both.

Jensen's survey technique is to present the principal contributions of each citation in a sentence or two. The review proceeds generally in chronological order. For the most part, the discussion is descriptive and nonanalytical. This technique is most useful for seeing the development in the area in broad terms and for identifying the literature sources that can be probed and evaluated later. What is lacking in this technique is helping the reader of the survey to discriminate between the really seminal contributions and those that are much less important. It is also impossible for the reader to be aware of the intellectual conflict that must have ensued as important concepts were debated, assessed, and became accepted by the profession.

French, on the other hand, takes a much narrower subject and approaches it in a more analytical fashion in part 2. Only 8% of the citations were published in the *Journal*, and 40% appeared before 1960. French's opening discussion of the various types of efficiency is worth the price of the book. By confining his purview to productive efficiency in agricultural marketing, he makes his task manageable. Rather than simply a survey of the work in the field, this piece is really a "state of the art" analysis. It is closely argued and evaluative. It is more difficult than the other parts but gives greater rewards in substantive knowledge to those who will master it. The economic-engineering approach, for which French and his California colleagues are justly famous, receives much of the play.

But this strength also contains a grain of weakness. A number of marketing issues that have been and are of interest to agricultural economists are not included in French's limited area. A case in point is the issue in market structure and concentration which is not treated anywhere in the volume except for a passing shot by Brandow in part 3.

George Brandow's "Policy for Commercial Agriculture" is useful, competent, insightful, and comprehensive. His survey is well balanced in terms of the literature reviewed, and all students of the subject at whatever level will benefit from referring to it time and again. The piece is so good, in fact, that I almost feel guilty in pointing out a

mistaken and annoying Brandow attitude, but I will anyway.

Brandow takes several shots at models of perfect competition, and some of them land below the belt. For example, "the writer will indulge himself in two comments on methods and approaches. As has already been suggested, he has little confidence in the productivity of analyses anchored in the assumptions of perfect competition, focused exclusively on resource allocation, and employing only logic, however elegant, to reach conclusions purporting to apply to policy issues. He would like to associate himself with the orientation toward the real world reflected in the Presidential addresses of Leontief and Galbraith to the American Economic Association" (p. 281). This statement misses the point about the use of economic models of perfect competition in policy analyses. If we, as agricultural economists, cannot say anything about the impacts of agricultural policy on efficiency, then is not our discipline largely sterile in this area? If we do not use the competitive model for analytical tasks, then which ones do we use? Can Brandow really be serious in stating that agricultural policy can best be analyzed by utilizing Galbraith's notions of power rather than traditional neoclassical competitive theory?

The fact that Brandow's piece is so long and yet is concisely presented is evidence enough of the tremendous complexity of American agricultural policy. Governmental intervention in U.S. agriculture has been highly varied in form and massive in quantity. What have we learned? Which policies have succeeded; which failed? The answers are far from clear. Perhaps it is still too early to say, even after nearly forty years, but I wish Brandow had attempted an answer. There is much at stake, and no one in the profession can match Brandow's expertise in this area.

What can be done with more limited objectives and analytical brilliance is beautifully illustrated by D. Gale Johnson's short essay, "Postwar Policies Relating to Trade in Agricultural Products." This is a real gem written by an economists' economist. After reading this survey, I felt I understood the central issues in this area. Johnson's primary theme is the conflict, too often unrecognized, between domestic agricultural policies and foreign trade policies. More than in any other survey in the book, Johnson weighs and evaluates, compliments, and blames. Only a small fraction of the literature cited, 11%, was published by the *AJAE* and none before 1960. Johnson is also generous with his own opinions about neglected areas of research, possibilities of resolving the conflict between domestic and trade policies, and ways to improve the functioning of international markets. This article should be required reading for every student of agricultural economics.

Our Cornell colleagues, Tomek and Robinson, have written the most technical piece in the volume, with the possible exception of French's. Their topic, "Price Analysis and Outlook," is quite broad; but they approach and treat it competently and comprehensively. I am content to let other reviewers, who know the area better than I do, serve in a critical role.

The piece by Brake and Melichar in the area of agricultural finance is quite different from the rest in approach and is highly rewarding. It is more current and has citations published as recently as April 1975, and even contains data updated to reflect revisions available as of July 1976. Several sections begin with presentation of historical data that place the later review of the literature in a more useful context. Such information on land prices, interest rates, debt, farm assets, farm income, and input prices is skillfully analyzed and the implications for capital formation and credit requirements are carefully explained. Brake and Melichar also are rather explicit in what we do and do not know in the area of their survey, and the section suggesting future research is very strong. It is difficult to see how this survey could have been improved. (My colleague, Rulon Pope, and I were working on a paper on the scale and structure of U.S. agriculture when I undertook this review. Much of our paper was concerned with farm numbers, farm size, and type of farm organization. We found Brake and Melichar's survey article particularly useful in identifying literature sources and believe we discovered first-hand the value of these surveys for this type of professional activity.) One must search hard to find any significant omissions, but I could not find any discussion of disaster relief programs which may be an important source of capital when producers need it most.

Before reading this book, it was not obvious to me that technical change deserved a separate chapter. After I had finished reading the book, however, the wisdom of the committee to include this topic was apparent to me. Perhaps more than anything else, an understanding of technical change is indispensible to understanding post-World War II U.S. agriculture. The final article by Peterson and Hayami on technical change is much like the Johnson paper in that it treats a more limited topic, and its approach is analytical. The authors do a competent job of defining technical change, identifying problems in its measurement, discussing its component parts, and reviewing its contribution to increased productivity. The substantive issues get central focus as literature sources are brought to bear, evaluated, and put into perspective. This piece was the most readable and most logically and clearly presented of any in the volume.

There is disappointingly little, however, on the fundamental issue of the relationships between technical change and economies of scale. While a section is devoted to economies of scale and scale bias, only one study is cited, and it has its geo-

graphic location in Mexico. If this is the most that can be said about such a basic issue, then we as a profession have much yet to do in this area. Peterson and Hayami's review clearly establishes that we know a great deal about "efficiency" aspects of technical change; how aggregate benefits compare with costs. We apparently know much less about the "equity" aspects, however, the distribution of the net benefits among producer and consumer groups.

I close this review with a warning that this book may be too good. It will be tempting to utilize it far beyond the optimal level and close our search for other literature before we should. Sloppy scholarship and unwarranted intellectual inbreeding will surely result if we do. Let us see it for what it is—tremendously useful but only a first step in literature search, review, and evaluation.

B. Delworth Gardner
University of California

Books Received

Allan, Mae. *Darwin and His Flowers: The Key to Natural Selection.* New York, Taplinger Publishing Co., 1977, 318 pp., $14.50.

Anderson, Lee G., and Russell F. Settle. *Benefit-Cost Analysis: A Practical Guide.* Lexington, Mass., Lexington Books, 1977, xiii + 140 pp., $15.00

Batten, James W., and J. Sullivan Gibson. *Soils. Their Nature, Classes, Distribution, Uses and Care.* Revised edition. University of Alabama Press, 1977, xi + 276 pp., $10.00.

Bhagwati, Jagdish N., ed. *The New International Economic Order: The North-South Debate.* Cambridge, MIT Press, 1977, ix + 390 pp., $9.95.

Breimyer, Harold F. *Farm Policy: 13 Essays.* Ames, Iowa State University Press, 1977, vii + 121 pp., $7.50.

Brown, Peter G., and Henry Shue, eds. *Food Policy. The Responsibility of the United States in the Life and Death Choices.* New York, The Free Press, 1977, vii + 344 pp., $14.95.

Carnesale, A., S. M. Greenfield, F. S. Hoffman, E. J. Mitchell, W. R. Moffat, R. Nehring, R. S. Pindyck, N. C. Rasmussen, D. J. Rose, H. S. Rowen, J. L. Sweeney, and A. W. Wright. *Options for U. S. Energy Policy.* San Francisco, Institute for Contemporary Studies, 1977, x + 309 pp., $5.95 paper.

Day, Richard H., and Indirjit Singh. *Economic Development as an Adaptive Process—The Green Revolution in the Indian Punjab.* New York, Cambridge Press, 1977, x + 326 pp., $24.95.

Duncan, E. R., ed. *Dimensions of World Food Problems.* Ames, Iowa State University Press, 1977, xi + 309 pp., $8.50.

Gibbons, Boyd. *Wye Island.* Baltimore, Johns Hopkins University Press, 1977, xiii + 227 pp., $10.95.

Gillmor, Desmond A. *Agriculture in the Republic of Ireland.* Budapest, Akademiai Kiado Publishing House, 1977, 201 pp., $13.00.

Granger, C. W. J., and Paul Newbold. *Forecasting Economic Time Series.* New York, Academic Press, 1977, xii + 324 pp., $22.00.

Hagler, M. O., and M. Kristiansin. *An Introduction to Controlled Thermonuclear Fusion.* Massachusetts, Lexington Books, 1977, xvii + 188 pp., price unknown.

Henson, J. B., and Marilyn Campbell, eds. *Theileriosis, Report of a Workshop Held in Nairobi, Kenya 7–9 December 1976.* Cosponsored by the International Laboratory for Research on Animal Diseases, and the International Development Research Center, Ottawa, Canada, 1977, 11 pp., $1.00 microfische edition.

Jedlicka, Allen D. *Organization for Rural Development. Risk Taking and Appropriate Technology.* New York, Praeger Publishers, 1977, xvi + 170 pp., $9.95.

Kabra, Kamal Nayan. *Planning Process in a District.* New Delhi, Indian Institute of Public Administration, 1977, ix + 110 pp., $8.00.

Kawharu, I. H. *Maori Land Tenure Studies of a Changing Institution.* New York, Oxford University Press, 1977, xi + 363 pp., $29.95.

Lin, Steven A. Y., ed. *Theory and Measurement of Economic Externalities.* New York, Academic Press, 1977, xiv + 265 pp., $19.50.

Lockeretz, William, ed. *Agriculture and Energy.* New York, Academic Press, 1977, xiii + 750 pp., $29.50.

Martin, Lee R., general ed. *A Survey of Agricultural Economics Literature, Volume 2.* Minneapolis, University of Minnesota Press, 1977, xxii + 473 pp., $25.00.

Norton, G. A., and C. S. Holling, eds. *Proceedings of a Conference on Pest Management.* Laxenburg, Austria, International Institute for Applied Systems Analysis, 1977, vi + 352 pp., $13.40.

Papageorgiou, George J. *Mathematical Land Use Theory.* Massachusetts, Lexington Book Division, D.C. Heath & Co., 1977, xx + 307 pp., $27.50.

Pearce, David W., and Ingo Walter. *Resource Conservation Social and Economic Dimensions of Recycling.* New York, New York University Press, 1977, xv + 383 pp., $28.50.

Ritson, Christopher. *Agricultural Economics—Principles & Policy.* New York, St. Martin's Press, 1977, xiii + 409 pp., $18.95.

Stamp, Elizabeth, ed. *Growing Out of Poverty.* New York, Oxford University Press, 1977, x + 165 pp., $9.95, $4.95 paper.

Tuma, Elias H., ed. *Food and Population in the Middle East.* Washington, D.C., 1976, Institute of Middle Eastern and African Affairs, 1976, 84 pp., price unknown.

van Eldren, E. *Heuristic Strategy for Scheduling Farm Operations.* The Netherlands, Wageningen, Centre for Agricultural Publishing and Documentation, 1977, 217 pp., $22.50.

Varjo, Uuno. *Finnish Farming. Typology and Economics.* Budapest, Akademiai Kiado Publishing House, 1977, 145 pp., $9.00.

Walinsky, Louis J., ed. *Agrarian Reform as Unfinished Business.* New York, Oxford University Press, 1977, xi + 603 pp., $22.00, $10.75 paper.

Waswo, Ann. *Japanese Landlords: The Decline of a Rural Elite.* Berkeley, University of California Press, 1977, viii + 152 pp., $10.00.

Weintraub, Sidney, ed. *Modern Economic Thought.* Philadelphia, University of Pennsylvania Press, 1977, xiv + 584 pp., $25.00.

Wyckoff, D. Daryl, and David H. Maister. *The Domestic Airline Industry.* Massachusetts, Lexington Books, 1977, xciv + 191 pp., price unknown.

Zolotas, Xenophon. *International Monetary Issues and Development Policies.* Athens, Bank of Greece, 1977, xxxi + 502 pp., price unknown.

News

Announcements

Annual Meeting, 1978

The annual meeting of the American Agricultural Economics Association will be held jointly with the Canadian Agricultural Economics Society 6–9 August on the campus of Virginia Polytechnic Institute and State University at Blacksburg.

Professor Lee Chambliss is chairman of the local arrangements committee, and correspondence concerning the meeting should be directed to him. Program information and registration forms will be provided in mailings from the local arrangements committee about the end of May. Preregistration is strongly urged in order to avoid the $5.00 late registration fee.

New Journal

The first issue of the *North Central Journal of Agricultural Economics*, sponsored by NCA-12, is scheduled for publication in September 1978. The objective of this new refereed journal is to complement *AJAE* by concentrating on reports of empirical work oriented to part or all of the North Central region.

Manuscripts in the area of research, teaching, and public service are welcome. Details regarding the format for manuscript submission are available upon request from the editor of *NCJAE*. The journal initially will be published semi-annually. Subscriptions are now being accepted at $5 per year. Make checks payable to *North Central Journal of Agricultural Economics*, and mail all correspondence regarding the journal to Lyle T. Fettig, editor, *NCJAE*, 305 Mumford Hall, University of Illinois, Urbana, Illinois 61801.

Third World Conference

The University of Nebraska at Omaha will host the Second National Conference on the Third World at the Hilton Inn 16–18 November.

Scholars and practitioners from third world nations will engage in a scholarly exchange of information, analyses, and ideas with U.S. academicians. This interdisciplinary meeting will encompass a broad range of topics, problems, and challenges identified with the Third World, and experts from all areas of scholarship are welcome to participate in the conference.

For additional information, contact Professor H. Carl Camp, program chairman, or Professor Joong-Gun Chung, Office of International Studies and Programs, University of Nebraska at Omaha, Omaha, Nebraska 68101, or telephone 402-554-2624.

International Agricultural Economics Association Conference

"Rural Change: The Challenge for Agricultural Economists" is the theme for the fiftieth anniversary—XVII Triennial International Conference of Agricultural Economists, to be held 3–12 September 1979, at Banff, Alberta, Canada.

Plenary and contributed papers will be organized around topics concerning needs, opportunities, and ways to improve agricultural economic services at micro or private levels, at subnational, national and international levels; and from the viewpoint of organizations which are either private or public in nature. Other contributions will discuss problems at the level of the discipline itself.

The 1978–79 membership fee of $20 is due now and can be mailed to R. J. Hildreth, Farm Foundation, 1211 W. 22nd Street, Oak Brook, Illinois 60521.

Conference on Economic and Demographic Change

The International Union for the Scientific Study of Population (IUSSP) will hold a conference on economic and demographic change in Helsinki, Finland, 28 August–1 September, hosted by Väestöliitto, the Finnish Population and Family Welfare Federation.

Participants will concern themselves with population and its relationship to resources and environment, international economic order, and long-term strategies for economic and demographic development. There will be special sessions on the following topics: population and economic change by development typology, covering structural changes in the economy—labor force, income distribution, and sectoral and spatial distribution—consumption, savings and investment, and economic aspects of age structure; economic-demographic interactions in rural development processes, covering mortality, fertility, rural labor force and employment, and rural out-migration; economic-demographic interactions in urbanization, covering patterns of urban growth, demographic aspects of urban planning, unemployment, and underemployment; the family and the economy, including household economic-demographic decision-making, and the economic implications of the demographic behavior of the family; international migration, considering causes, theories,

consequences, and alternatives of international migration; and a specialized session on disciplinary perspectives of economic demography.

Registration fees cover participation, reception, solicited papers, and the proceedings, and are $70 for IUSSP members, $90 for nonmembers, and $20 for accompanying persons. Payment of registration fees before 31 May will earn a discount of $20. Queries, fees, and registration information should be sent to Bruno Remiche, executive secretary, International Union for the Scientific Study of Population, Rue Forgeur 5, 4000 Liege, Belgium.

AAEA COMMITTEE STRUCTURE, 1977–78

Ad Hoc Committees

Edward W. Browning Award Nominations

A. Gordon Ball, Chairman, University of Guelph
Robert J. Bevins, University of Missouri
Irving Dubov, University of Tennessee
J. Edwin Faris, Clemson University
Terry F. Glover, Utah State University
A. H. Harrington, Washington State University
John D. Helmberger, University of Minnesota
Larry J. Martin, University of Guelph

Non-Land-Grant Member Services

William D. Herr, Chairman, Southern Illinois University
David Y. Chen, North Carolina A&T University
Leroy Davis, Southern University
R. Vern Elefson, Wisconsin State University
Robert J. Williams, East Michigan University

Special Committees

Alternative Publications

Verner G. Hurt, Chairman, Mississippi State University, 1975
Harold F. Breimyer, University of Missouri, 1975
Ben C. French, University of California, Davis, 1975
Glenn E. Heitz, Federal Land Bank of St. Louis, 1976
Sylvia Lane, University of California, Davis, 1977 (Board Rep.—one-year term)
Paul E. Nelson, Economics, Statistics, and Cooperatives Service, USDA, 1975
Stephen C. Smith, University of Wisconsin, 1975
Glen V. Vollmar, University of Nebraska, 1975
Gene Wunderlich, Economics, Statistics, and Cooperatives Service, USDA, 1977

Board Advisory on Fellow Nomination

Richard T. Crowder, Chairman, The Pillsbury Company, 1977 (one-year term)
John Redman, University of Kentucky, 1977
Edward Schuh, Purdue University, 1977 (two-year term)

Contributed Papers

Clark Edwards, Chairman, Economics, Statistics, and Cooperatives Service, USDA, 1977 (one-year term)
Chauncey T. Ching, University of Nevada, 1976 (three-year term)
Martin K. Christiansen, University of Minnesota, 1976 (two-year term)
Larry J. Connor, Michigan State University, 1977 (three-year term)
Milton C. Hallberg, Pennsylvania State University, 1976 (two-year term)
Darrell L. Hueth, University of Rhode Island, 1977 (three-year term)
Frederick L. Leistritz, North Dakota State University, 1977 (three-year term)
James A. Niles, University of Florida, 1976 (three-year term)
J. Martin Redfern, University of Arkansas, 1976 (two-year term)
Odell Walker, Oklahoma State University, 1976 (three-year term)
T. Kelley White, Purdue University, 1976 (three-year term)

Evaluation of Annual Meeting

Henry J. Meenan, Chairman, University of Arkansas, 1975
Charles L. Beer, Science and Education Administration, USDA, 1975
Joseph D. Coffey, Virginia Polytechnic Institute and State University, 1975 (Board Rep.—one-year term)
Otto C. Doering, Purdue University, 1975
Richard J. Herder, Central Soya, 1975
John G. McNeely, Texas A&M University, 1975
Kenneth C. Nobe, Colorado State University, 1975
Lawrence W. Witt, U.S. Department of State, 1975

Extension Affairs

W. Fred Woods, Chairman, Science and Education Administration, USDA, 1976
Wallace Barr, Ohio State University, 1977 (Board Rep.—one-year term)
Robert L. Christensen, University of Massachusetts, 1975
Norbert Dorow, North Dakota State University, 1975
W. S. Farris, Purdue University, 1975
Ralph E. Hepp, Michigan State University, 1977
Eddy L. LaDue, Economics, Statistics, and Cooperatives Service, USDA, 1977
Gene Nelson, Oregon State University, 1975
Bobby H. Robinson, Clemson University, 1975
William W. Wood, University of California, Riverside, 1976

Industry Affairs

Walter M. Myers, Chairman, Conti-Commodity, Inc., 1975
Donald A. Ault, Land-O-Lakes, 1976
Richard A. Benson, Caterpillar Tractor, 1976
John A. Knechel, Council of California Growers, 1976
Howard Madsen, General Foods, 1977
Bob Reynold, Safeway, 1977
Bruce A. Scherr, Data Resources, Inc., 1975
Edward Schuh, Purdue University, 1977 (Board Rep.—one-year term)
John Urbanchuck, Campbells Soup, 1977

International

Harold M. Riley, Chairman, Michigan State University, 1975
Ralph W. Cummings, Jr., International Agricultural Development Service, 1976
Roger W. Fox, University of Arizona, 1977
Charles B. Hanrahan, Economics, Statistics, and Cooperatives Service, USDA, 1976
William C. Merrill, Agency for International Development, 1975
Kenneth C. Nobe, Colorado State University, 1976
Philip Raup, University of Minnesota, 1977 (Board Rep.—one-year term)
Francis Van Gigch, World Bank, 1976
Abraham M. Weisblat, Agricultural Development Council, 1973

Literature Retrieval

Wayne D. Rasmussen, Chairman, Economics, Statistics, and Cooperatives Services, USDA, 1976
Hilly W. Fuchs, Continental Grain, 1976
James R. Gray, New Mexico State University, 1976
Philip L. Martin, University of California, Davis, 1976
Elmer L. Menzie, University of Guelph, 1976
Robert E. Olson, South Dakota State University, 1976
Rudie W. Slaughter, University of Missouri, Economics, Statistics, and Cooperatives Service, USDA, 1976
Cecil N. Smith, University of Florida, 1976
Raymond C. Smith, University of Delaware, 1974
Harry C. Trelogan, Arlington, Virginia, 1976

Management, Structure, Methods, and Procedures

W. Burt Sundquist, Chairman, University of Minnesota, 1976
Wallace Barr, Ohio State University, 1976
Richard T. Crowder, The Pillsbury Company, Minneapolis, 1976
Lou M. Eisgruber, Oregon State University, 1976
Neil Harl, Iowa State University, 1976
Leo Polopolus, University of Florida, 1976
John G. Stovall, Economics, Statistics, and Cooperatives Service, USDA, 1976

Nominating

Kenneth R. Farrell, Chairman, Economics, Statistics, and Cooperatives Service, USDA
B. D. Gardner, University of California
Eugene E. Gerke, Gerke Economics
Glenn S. Himes, Ohio State University
Fred D. Sobering, Kansas State University
A. M. Weisblat, Agricultural Development Council
C. E. Willis, University of Massachusetts
(All one-year terms)

Professional Registries & Employment

David H. Boyne, Co-chairman, Ohio State University, 1975
Loys Mather, Co-chairman, University of Kentucky, 1970
David M. Bell, Connell Commodities, 1975
Raymond R. Beneke, Iowa State University, 1975
Richard T. Crowder, The Pillsbury Company, 1977 (Board Rep.—one-year term)
G. R. Dowdy, Tuskegee Institute, 1974
Steven B. Harsh, Michigan State University, 1973
John Hopkin, Texas A&M University, 1977
Allan S. Johnson, Economics, Statistics, and Cooperatives Service, USDA, 1977
Paul L. Kelley, Kansas State University, 1976
John Malone, Pennsylvania State University, 1977
James S. Plaxico, Oklahoma State University, 1975

Publication of Postwar Literature Review

Emerson M. Babb, Chairman, Purdue University, 1974
J. Patrick Madden, Pennsylvania State University, 1974
Lee R. Martin, University of Minnesota, 1976
John C. Redman, University of Kentucky, 1974

Standing Committees

Awards

A. Gordon Ball, General Chairman, University of Guelph

Distinguished Extension Programs

Robert J. Bevins, Chairman, University of Missouri, 1975
Charles W. Coale, Virginia Polytechnic Institute and State University, 1975
Wayne A. Hayenga, Texas A&M University, 1976
Harlan Hughes, Michigan State University, 1977
Sherril B. Nott, Michigan State University, 1977
Ray Prigge, University of Idaho, 1975
Paul R. Robbins, Purdue University, 1976

Lois A. Simonds, Ohio State University, 1977
David L. Trammell, Mississippi State University, 1977

Distinguished Policy Contributions

J. Edwin Faris, Chairman, Clemson University, 1977 (three-year term)
Brady J. Deaton, University of Tennessee, 1977 (two-year term)
R. Brian How, Cornell University, 1977 (two-year term)
LaVaughn Johnson, University of Georgia, 1977 (one-year term)
Donald Kaldor, Iowa State University, 1977 (one-year term)
Billy V. Lessley, University of Maryland, 1977 (three-year term)
Dan Padberg, University of Illinois, 1977 (one-year term)
Allen B. Paul, Economics, Statistics, and Cooperatives Service, USDA, 1977 (three-year term)
J. B. Penn, Council of Economic Advisors, 1977 (three-year term)
Charles Pugh, North Carolina State University, 1977 (two-year term)

Distinguished Undergraduate Teaching

John D. Helmberger, Chairman, University of Minnesota, 1976
Maurice J. Danner, Auburn University, 1975
Donald B. Erickson, Kansas State University, 1976
Paul E. Nesselroad, West Virginia University, 1976
James E. Osborn, Oklahoma State University, 1975
Paul Roy, Louisiana State University, 1977
Kenneth C. Schneeberger, University of Missouri, 1975
Ronald W. Ward, University of Florida, 1977

Outstanding Doctoral Programs

Terry F. Glover, Chairman, Utah State University, 1975
Dale G. Anderson, University of Nebraska, 1976
Harry W. Ayer, University of Arizona, 1975
Richard Bishop, University of Wisconsin, 1977
Dale C. Dahl, University of Minnesota, 1975
Walter Haessel, Pennsylvania State University, 1976
Dale M. Hoover, North Carolina State University, 1976
Ed F. Jansen, University of New Hampshire, 1975
Richard E. Just, University of California, Berkeley, 1976
Clyde F. Kiker, University of Florida, 1977
John R. Moore, University of Maryland, 1977
Melvin D. Skold, Colorado State University, Economics, Statistics, and Cooperatives Service, USDA, 1976
Ronald W. Ward, University of Florida, 1976

Outstanding Master's Programs

Larry J. Martin, Chairman, University of Guelph, 1976
Thomas Carlin, Economics, Statistics, and Cooperatives Service, USDA, 1975
Thomas Daves, South Dakota State University, 1975
Frank M. Goode, Pennsylvania State University, 1977
Delmer L. Helgeson, North Dakota State University, 1977
Frederick J. Hitzhusen, Ohio State University, 1976
Verne W. House, Montana State University, 1977
F. Richard King, University of Maine, 1976
James McGrann, Iowa State University, 1977
John Nichols, Texas A&M University, 1977
Anne Peck, Food Research Institute, Stanford University, 1976
Steve Reiling, Louisiana State University, 1977
Robert O. Sinclair, University of Vermont, 1977

Publications, Quality of Communication

David E. Kenyon, Chairman, Virginia Polytechnic Institute and State University, 1976
W. G. Aanderud, South Dakota State University, 1975
Frank S. Conklin, Oregon State University, 1977
Kenneth D. Duft, Washington State University, 1976
Harold D. Guither, University of Illinois, 1976
Sidney Ishee, University of Maryland, 1975
William E. Martin, University of Arizona, 1976
James L. Pearson, Economics, Statistics, and Cooperatives Service, USDA, 1976

Publications, Quality of Research Discovery

Irving Dubov, Chairman, University of Tennessee, 1975
Oscar R. Burt, Montana State University, 1977
Gerry Carlson, North Carolina State University, 1977
James B. Hassler, University of Nebraska, 1976
James F. Hudson, Louisiana State University, 1976
James J. Jacobs, University of Wyoming, 1977
John Miranowski, Iowa State University, 1977
Timothy D. Mount, Cornell University, 1977
Andrew Schmitz, University of California, Berkeley, 1976

Publications of Enduring Quality

A. H. Harrington, Chairman, Washington State University, 1975
George J. Conneman, Jr., Cornell University, 1976
Gerald A. Doeksen, Oklahoma State University,

Joseph C. Headley, University of Missouri, 1976
J. C. Hite, Clemson University, 1977
Neil R. Martin, University of Georgia, Economics, Statistics, and Cooperatives Service, USDA, 1975
Stanley K. Seaver, University of Connecticut, 1976
Richard Shumway, Texas A&M University, 1977
Stephen H. Sosnick, University of California, Davis, 1975

Economic Statistics

Luther G. Tweeten, Chairman, Oklahoma State University, 1974
Arlo W. Biere, Kansas State University, 1976
Norman M. Coats, Ralston Purina Company, 1975
Bruce Gardner, Texas A&M University, 1977
William E. Kibler, Economics, Statistics, and Cooperatives Service, USDA, 1976
Glenn Nelson, University of Minnesota, 1977
Edward I. Reinsel, Economics, Statistics, and Cooperatives Service, USDA, 1977
Norman K. Whittlesey, Washington State University, 1976
Gaylord E. Worden, Economics, Statistics, and Cooperatives Service, USDA, 1974

Fellows Election

Vernon W. Ruttan, Chairman, University of Minnesota, 1974
Emery Castle, Resources for the Future, 1976
Ken Farrell, Economics, Statistics, and Cooperatives Service, USDA, 1977 (Board Rep.—one-year term)
Lauren K. Soth, Des Moines Register and Tribune, 1973
Earl Swanson, University of Illinois, 1977
Holbrook Working, Stanford University, 1975

Finance

Wallace Barr, Chairman, Ohio State University, 1975
Michael D. Boehlje, Iowa State University, 1975
John Brake, Michigan State University, 1977
Joseph Coffey, Virginia Polytechnic Institute and State University, 1977
John C. Redman, University of Kentucky, 1974

Membership

Thomas L. Frey, Chairman, University of Illinois, 1975
Thomas Clevenger, New Mexico State University, 1976 (WAEA Rep.)
John E. Cottingham, Wisconsin State University, 1975
Arthur Duarte, California Polytechnic Institute, San Luis Obispo, 1977
John D. Graham, University of British Columbia, 1975
Reed Hertford, Ford Foundation, 1976
Sylvia Lane, University of California, Davis, 1976 (Board Rep.—one-year term)
Loyd C. Martin, Economics, Statistics, and Cooperatives Service, USDA, 1977
Karl D. Meilke, University of Guelph, 1977 (CAES Rep.)
Theodore F. Moriak, Office of Management and Finance, USDA, 1976
Robert Raunikar, University of Georgia, 1977 (SAEA Rep.)
Donald Stitts, University of Connecticut, 1976 (NAEC Rep.)

Professional Activities

Paul W. Barkley, Chairman, Washington State University, 1975
Dan Bromley, University of Wisconsin, 1977
William D. Herr, Southern Illinois University, 1977
Kenneth D. McIntosh, West Virginia University, 1975
J. Paxton Marshall, Virginia Polytechnic Institute and State University, 1977
Philip M. Raup, University of Minnesota, 1975 (Board Rep.)
Bruce A. Scherr, Data Resources, 1976
Gary L. Seevers, Commodity Futures Trading Commission, 1977
Gene L. Wunderlich, Economics, Statistics, and Cooperatives Service, USDA, 1975

Resident Instruction

Carl W. O'Connor, Chairman, Oregon State University, 1976
Raymond Folwell, Washington State University, 1977
A. Robert Koch, Rutgers University, 1975
Marvin W. Kottke, University of Connecticut, 1976
Hong Y. Lee, Texas Tech University, 1975
Kregg McKenney, Texas Tech University, 1977 (Undergraduate Rep.)
Donald Mitchell, Michigan State University, 1977
David B. Narrie, Tennessee State University, 1977

Tellers Committee

Lynn W. Robbins, Chairman, University of Kentucky, 1977
Joe T. Davis, University of Kentucky, 1977

Liaison Representatives

Representative to the Agricultural Development Council and Research and Training Network

C. Peter Timmer, Cornell University, 1974 (three-year term)

Representative to the American Society of Agronomy

Jerry B. Eckert, Colorado State University, 1976 (three-year term)

Representative to the Bureau of Census Advisory Committee on Agricultural Statistics

M. L. Upchurch, University of Florida, 1975 (three-year term)

Representative to the Federal Statistics Users Conference

Norman M. Coats, Ralston Purina Company, 1975 (three-year term)

Representative to the National Bureau of Economic Research

G. Edward Schuh, Purdue University, 1976 (three-year term)

Representative to the National Research Council

John C. Redman, University of Kentucky

U.S. Council of the International Association of Agricultural Economists, 1976–79

Norman R. Collins, Ford Foundation
Allen B. Paul, Economics, Statistics, and Cooperatives Service, USDA
Lyle P. Schertz, Economics, Statistics, and Cooperatives Service, USDA
J. B. Wyckoff, Oregon State University

Personnel

Agricultural Development Council

Appointments: Brian A. Lockwood, formerly with the East-West Institute, University of Hawaii, is Council associate at Faisalabad Agricultural University, Pakistan; **Arthur T. Mosher** has assumed interim presidency of the ADC as of 1 January; **James A. Roumasset,** formerly with the Department of Economics, University of Hawaii, is Council specialist at the Institute for Agricultural Development and Administration, University of the Philippines, Los Banos.

University of Arizona

Return: John Fischer, Director, African Programs, Consortium for International Development, is a professor.

Auburn University

Appointment: Neil R. Martin, formerly with ERS, U.S. Department of Agriculture, Athens, Georgia, is associate professor in farm management and production economics.

University of California, Davis

Resignation: Daryl E. Carlson, a rancher in the Turlock area, is now at California State College, Stanislaus.
Honor: J. Herbert Snyder was elected a Fellow of the Soil Conservation Society of America, in April 1977.

Clemson University

Appointments: Mark S. Henry, formerly at the University of North Dakota, is an associate professor in regional economics; **Frances Wenzel Kaizer,** M.S. Iowa State University, is visiting instructor in land economics.
Resignation: R. Kenneth DeHaven, associate professor of dairy marketing, is in private business.

ADC: Agricultural Development Council; **ASCS:** Agricultural Stabilization and Conservation Service; **CED:** Commodity Economics Division; **EDD:** Economic Development Division; **ERS:** Economic Research Service; **FDCD:** Foreign Demand and Competition Division of ERS; **NEAD:** National Economic Analysis Division of ERS; **NRED:** National Resource Economics Division of ERS.

Note: In January of this year, the Economic Research Service merged with three other USDA agencies to form the Economics, Statistics, and Cooperatives Service (ESCS).

Colorado State University

Appointment: Melvin D. Skold, formerly with ERS-USDA, is a professor of economics with teaching and research responsibilities in agricultural production economics.
Resignations: Assistant professor **Philip L. Knox** has entered a family business in Kansas; **Anthony A. Prato** is with the U.S. Department of Energy, Washington, D.C.

Cornell University

Appointments: Ransom A. Blakeley is a senior extension associate; **Jon Conrad,** Ph.D. University of Wisconsin, **William H. Lesser,** Ph.D. University of Wisconsin, and **Gerald White,** Ph.D. Pennsylvania State University, are assistant professors; **Geoffrey C. Swenson,** on leave from ADC, is a visiting fellow.
Honor: C. Arthur Bratton, professor of farm management, received the Epsilon Sigma Phi Superior Performance Award for outstanding work and program on state and retirement planning, as well as for his overall leadership in the extension program.

University of Delaware

Leave: G. Joachim Elterich will spend part of his sabbatical leave 1977–78, with AID, Bureau for Development Support.

Federal Intermediate Credit Bank of Louisville

Retirement: Lester L. Arnold, former vice president, after 37 years of service with USDA, the Agricultural Extension Service, and the Farm Credit System.

University of Guelph

Leave: Stewart H. Lane is on leave with the Ministry of Agriculture and Fisheries, New Zealand, and the Department of Agriculture, New South Wales, Australia.
Honors: The Canadian Agricultural Economics Society Awards for 1977 were presented to **John R. Groenewegen** and **Douglas C. Holliday** for outstanding master of science theses; to **Herbert C. Driver** and **S.J.B. Stackhouse** (Truro Agricultural College) for outstanding article in the *Canadian Journal of Agricultural Economics,* and to **Larry J. Martin** and **Donald MacLaren** (University of Aberdeen) honorable mention for outstanding article in the same journal.

University of Illinois

Appointment: Emmett Elam is extension associate.
Leave: M. B. Kirtley is on leave with the USDA in Washington, D.C. until 1 July 1979.

Iowa State University

Appointments: Lizardo de las Casas is a temporary assistant professor, **Wallace C. Hardie** is an instructor, and **Robert J. Hauser** is a research associate, all in the Department of Economics.

Kansas State University

Appointment: Norman V. Whitehair is an extension economist in livestock marketing and agricultural firm management.
Retirement: Jay L. Treat, area extension economist—Farm Management Association, has retired.

University of Kentucky

Appointment: Steven K. Riggins, Ph.D. Cornell University, is an assistant professor of marketing.
Retirements: Ernest Gooch, Jr., has retired after 29 years of service, and **Willard H. Minton,** after 25 years of service.

Michigan State University

Appointments: T. K. Cowden, professor emeritus, has returned from Washington, D.C. assignments with USDA, and is teaching agricultural policy; **Harlan Hughes,** formerly at the University of Wisconsin, is associate professor, with extension outlook as his primary assignment; and **Benedict Stavis,** formerly with Cornell University, is assistant professor, working on alternative rural development strategies.
Leaves: James T. Bonnen is on leave during 1978 with the Office of Management and Budget, Washington, D.C. He will lead a task force considering reorganization of the federal statistical system.

University of Minnesota

Appointment: Patrick D. Meagher, B.S. University of Wisconsin, is a research specialist in economic analysis of the development potential for copper-nickel resources in northeastern Minnesota.
Resignation: Nasser Aulaqu, assistant professor, has accepted an appointment as lecturer at Sana'as University, Yemen Arab Republic.

Oklahoma State University

Appointments: James E. Osborn, former assistant dean in charge of research, College of Agricultural Sciences, and chairman, Department of Agricultural Economics at Texas Tech University, is new department chairman; **Alan E. Baquet,** formerly at Michigan State University, is an assistant professor in the area of commercial agriculture; **Gerald A. Doeksen,** formerly with EDD/ERS/USDA, is associate professor in rural development.
Leave: John Goodwin is director of ASCS in Oklahoma.
Resignation: Michael S. Salkin, former assistant professor, is with Bank of America, in San Francisco.
Retirements: Dean E. Barrett, former associate professor, has retired after 26 years of service; former associate professor **Robert E. Daugherty,** after 31 years of service; and former professor **Houston E. Ward,** after 39 years of service.

Pennsylvania State University

Appointment: James Dunn has been appointed as an assistant professor of transportation.
Leaves: Robert Bealer is on a six-month sabbatical to prepare a monograph on the role of sociological theory in applied rural sociology; **James Holt** is on leave with the U.S. Department of Labor, Washington, D.C., for one year; **Fred Hughes** has taken leave to prepare an adult education course on estate planning.

Prairie View A&M University

Retirement: Vance W. Edmondson retired from a joint appointment with Texas A&M University and Prairie View A&M University, after 21 years' service.

Purdue University

Appointments: David Bessler, Ph.D., University of California-Davis, is assistant professor; **Craig Dobbins,** Ph.D., Oklahoma State University, and **John Spriggs,** Ph.D., University of Minnesota, are assistant professors.

Southern Illinois University, Carbondale

Appointment: George Shumaker, Ph.D., University of Georgia, is an assistant professor.

Stanford University, Food Research Institute

Appointments: Eduardo Garcia and **Leon Mears** are visiting scholars; **John Page** is research associate/ lecturer Jan.-June 1978.

University of Tennessee

Appointment: Ronald W. Todd is associate professor of agricultural economics and law.

Texas A&M University

Appointments: Carl Anderson, former economist with the Dallas Federal Reserve Bank, is extension cotton marketing specialist; **Michael L. Cook,** formerly with New Mexico State University, is an assistant professor; **Judon Fambrough,** formerly in private legal practice, is lecturer in agricultural law; and **James W. Richardson,** formerly with Oklahoma State University, is an assistant professor.

U.S. Department of Agriculture

Appointments in CED: David E. Banker is assigned to the Dairy Program Area; **Thomas M. Bell** has joined the Forecast Support Group; **Keith J. Collins** is with the Fibers and Oils Program Area; and **Randall M. Russell** is with the Forecast Support Group.
Appointments in EDD: Frank Fratoe is in the Health and Education Program Area; **Richard E. French** is in the Regional Analysis Program area.
Appointment in NEAD: William W. Lin joined the Structure and Adjustments Program Area.
Appointments in NRED: John Bratland, William Quinby, Katherine Reichelderfer, Ray Stanton, Craig Tinney, and **Robert Toria** are assigned to the Environmental Studies staff.
Reassignments in CED: O. A. Cleveland transferred from the Fibers and Oils Program Area, Stoneville, Mississippi, to the Extension Service in Mississippi; **Dave Culver** transferred from the Agricultural Policy Analysis Program Area to FDCD; **James L. Driscoll,** Grains and Feeds Program Area, CED, transferred to the Federal Grain Inspection Service; **J. B. Penn,** of CED's Agricultural Policy Analysis Program Area transferred to the Council of Economic Advisors; **Thomas A. Stucker** transferred from the Agricultural Policy Analysis Program Area, CED, to NEAD; **John E. Trierweiler,** of CED's Meat Animals Program Area in Corvallis, Oregon, transferred to NRED.
Reassignments in NEAD: Herman Delvo and **Walter Ferguson** transferred to NRED's Environmental Studies Staff.
Reassignments in NRED: B. Ted Kuntz, of the River Basin Planning Staff, Corvallis, Oregon, recently transferred to NRED's Environmental Studies Staff at Corvallis; **John Parks,** of the River Basin Planning Staff at Raleigh, North Carolina, transferred to NRED's Environmental Studies Staff in Washington, D.C.
Reassignments in ESCS Administrative Staff: Quentin M. West, former administrator, ERS, is now Special Assistant to Assistant Secretary of Agriculture Hathaway, for international, scientific, and technical cooperation. **Kenneth R. Farrell,** former deputy administrator, ERS, is now Acting Administrator for Economics, Statistics, and Cooperatives Service (formerly ERS).
Resignations in CED: Whitman M. Chandler, Jr., resigned from the Fibers and Oils Program Area, CED, Washington, D.C. office.
Resignation in EDD: Gerald Doeksen resigned from the Regional Analysis Program Area, Stillwater, Oklahoma, to accept a position at Oklahoma State University.
Resignation in NEAD: Gordon E. Rodewald, formerly with the Structure and Adjustments Program Area, is on a two-year assignment in Africa for the International Development Staff, USDA.
Resignation in NRED: John Wilkins, River Basin Planning Staff, Corvallis, Oregon, accepted a position with the Bonneville Power Administration, Portland, Oregon.
Retirements in CED: Alfred J. Burns retired from the Fruits, Vegetables, Sweeteners and Tobacco Program Area, after 17 years of federal service; **Ervin O. Ullrich, Jr.,** Grains and Feeds Program Area, South Dakota, retired after 25 years of federal service.
Retirements in EDD: Jackson McElveen retired from the Regional Analysis Program Area, Clemson, South Carolina, after 31 years of federal service; **Grant Youmans** retired from the Health and Education Program Area, Lexington, Kentucky, after 32 years' service.

Virginia Polytechnic Institute and State University

Retirement: M. Calvin Conner, former professor, retired 28 December 1977, after 31 years of service in the Department of Agricultural Economics.

University of Wisconsin

Appointments: R. A. Luening is chairman of the Farm Business and Finance Committee, University of Wisconsin Extension.
Honors: John Strasma was cited by the Wisconsin legislature for contributing to the analysis of mineral taxation alternatives and the design of the comprehensive net proceeds tax which was enacted in June 1977.

World Bank

Appointment: Malcolm D. Bale, formerly at Montana State University, is an economist with the World Bank.

Other Appointments

Robert Allain, M.S. University of Arkansas, is a market analyst with Riceland Foods, Inc., Stuttgart, Arkansas.
Eddie D. Cross, M.S. University of Arkansas, is a researcher at the University of Illinois, Urbana.
Arthur J. Dommen, Ph.D. University of Maryland, is with the AID integrated rural development project at Maktar, Tunisia.
Jefferson Edwards, M.S. University of Arkansas, is a sales representative with the Doanes Dog Food Company, Joplin, Mo.
Edward Fryar, M.S. University of Arkansas, accepted a research position at the University of Minnesota, St. Paul.
Ralph Gunderson, Ph.D. University of Arkansas, is assistant professor of economics, Southeast Missouri State University, Cape Girardeau.
Tommy Hignight, M.S. University of Arkansas, is with the Production Credit Association, Hot Springs, Arkansas.
R. McFall Lamm, Jr., Ph.D. Virginia Polytechnic Institute and State University, is an economist with CED.
Michael V. Martin, Ph.D. University of Minnesota, is assistant professor in the Department of Agricultural and Resource Economics, Oregon State University.
Stephen E. Miller, Ph.D. Virginia Polytechnic Institute and State University, is an assistant professor at Clemson University.
Ewell Welch, M.S. University of Arkansas, is director of poultry marketing, Commodity Division, Arkansas Farm Bureau, Little Rock.
Michael Woods, M.S. University of Arkansas, is doing research at the Oklahoma State University, Stillwater.

Ph.D. Recipients by Subject

Agricultural Economics, General

Yang Boo Choe, B.S. Seoul National University, 1968; M.S. Seoul National University, 1972; Ph.D. University of Missouri, "An Essay on the Idea and Logic of Agricultural Economics."
Bryan Wilfred Schurle, B.A. Kansas State Teachers College, 1972; M.S. Ohio State University, 1974; Ph.D. Ohio State University, "An Analysis of the Return Risk Trade-Offs Associated with Tomato Production in Northwestern Ohio."
Augusto Cesar de Monteiro Soares, B.S. Federal University of Ceara, 1970; M.S. Ohio State University, 1974; Ph.D. Ohio State University, "Resource Allocation and Choice of Enterprise Under Risk on Cotton Farms in Northeast Brazil."
Charles L. Wright, B.A. University of Michigan, 1968; M.S. University of Sao Paulo, Brazil, 1973; Ph.D. Ohio State University, "The Economics of Grain Transportation and Storage: A Brazilian Case Study."

Agricultural Finance, Capital and Credit

Jagdeesh Chandra Kalla, B.S. University of Rajasthan, 1960; M. S. Agr University, 1962; Ph.D. Ohio State University, "Saving Investment Behavior of Farm Families—Udaipur District—Rajasthan (India)."

Agricultural Income; Rural Poverty

Ignez G. Lopes, B.S. University of Minas Gerais, Brazil, 1969; M.S. University of Vicosa, 1974; Ph.D. Purdue University, "Time Allocation of Low-Income Brazilian Households: A Multiple Job Holding Model."
Peter Joseph Matlon, B.S. Georgetown University, 1967; M.P.A. Princeton University, 1971; Ph.D. Cornell University, "The Size Distribution, Structure, and Determinants of Personal Income Among Northern Farmers in the North of Nigeria."

Agricultural Labor; Rural Manpower

Antonio L. Bandeira, B.S. Faculdade de Ciencias Economicas da UFMG, 1966; M.S. Universidade Federal de Vicosa, 1969; Ph.D. Purdue University, "Capital-Labor Ratios in Small Rural Firm-Households in Brazil."

The names of Ph.D. recipients are provided by departments of agricultural economics and by departments of economics with majors in agricultural economics. The list is for degrees granted in the calendar year 1977, unless otherwise stated.

Wadsworth Scott Cauchois, Jr., B.S. University of California, Berkeley, 1967; M.S. University of California, Davis, 1968; Ph.D. University of California, Davis, "Federal Manpower Programs in San Joaquin County, 1963–73: Magnitudes and Impacts."
M. A. Fernandez, B.S. Universidad de los Andes, Colombia, 1970; Ph.D. University of Manitoba, "Evaluation of Manpower Training Programs: The Interlake Manpower Corps."
Antonio Garcia-Ferrer, Graduate University of Madrid, 1973; Ph.D. University of California, Berkeley, "Rural Internal Migration, Employment Growth, and Inter-Regional Wage Differentials in Spain."
Chun-yang Hsu, B.S. National Taiwan University, 1965; M.S. University of Guelph, 1969; Ph.D. North Carolina State University, "Education, Production and Labor Substitution in Agriculture."
Kang Sik Park, B.S. Agr. Chonan National University, Korea, 1966; M.S. University of Hawaii, 1970; Ph.D. University of Hawaii, "Rural-Urban Labor Migration, Farm Structure Factor Productivity and Farm Income in Korean Agriculture."

Agricultural Products: Demand, Supply, Prices

Benjamin Acquah, B.S. University of Ghana, 1971; M.S. Colorado State University, 1972; Ph.D. University of Wisconsin, "An Analysis of Demand for Food Commodities in the Eastern Region of Ghana."
Muhammad S. Anjum, B.S. West Pakistan Agricultural University, 1968; M.S. West Pakistan Agricultural University, 1971; Ph.D. University of Hawaii, "Characteristics of Milk Consumption and the Development of Fluid Milk Processing in Lahore, Pakistan."
Mohd Sheffie Bakar, B.A. University of Malaysia, 1967; M.S. Purdue University, 1971; Ph.D. University of Wisconsin, "An Economic Analysis of Supply Response of Rice Acreage and Management of Rice Reserves in Peninsular Malaysia."
Paul Kenneth Blakely, B.Bus.Adm. Loyola University, 1968; M.S. McMaster University, 1969; Ph.D. Virginia Polytechnic Institute and State University, "A Quarterly Feeder Cattle Price Forecasting Model with Application Towards the Development of a Futures Market Strategy."
Jon Alan Brandt, B.S. Ohio State University, 1970; M.S. Ohio State University, 1970; Ph.D. University of California, Davis, "An Economic Analysis of the Processing Tomato Industry."
John Arvil Craven, B.S. Texas Tech University, 1970; M.S. Texas Tech University, 1972; Ph.D. University of Illinois, "An Econometric Analysis

of the United States Feed Grain-Livestock Economy."

David Earl Cummins, B.S. Ohio State University, 1960; M.S. Ohio State University, 1962; Ph.D. University of Minnesota, "Resource Productivity on Grade A Dairy Farms in the Twin Cities Milk Marketing Area."

Joe H. Dewbre, B.S. Oklahoma State University, 1971; M.S. New Mexico State University; Ph.D. Washington State University, "An Analysis of the Potentials for Using Midwest Futures Contracts to Increase Storage Earnings on Pacific Northwest Wheat."

Steven Paul Erickson, B.S. Purdue University, 1971; M.S. Purdue University, 1973; Ph.D. University of Illinois, "Empirical Analyses of Price Relationships in the Live Beef Futures Market—Implications for Primary Producers."

Khaisri S. Konjing, B.S. Kasetsart University, 1968; M.S. Michigan State University, 1970; Ph.D. University of Minnesota, "An Analysis of the Economic Performance of the U.S. Corn Futures Market."

Abraham Melamed, B.S. Hebrew University, Israel, 1960; M.S. Hebrew University, 1965; Ph.D. University of California, Berkeley, "The Citrus Marketing Board of Israel and the Auction Demand for Weekly Sales."

William Henry Meyers, B.A. Goshen College, 1963; M.S. University of the Philippines, 1970; Ph.D. University of Minnesota, "Long-Run Income Growth and World Grain Demand: An Econometric Analysis."

Stephen Ernest Miller, B.S. North Carolina State University, 1972; Ph.D. Virginia Polytechnic Institute and State University, "Live Hog Futures Prices as Expected Prices in the Empirical Modeling of the Pork Sector."

Dwight Douglas Minami, B.S. University of California, Davis, 1969; M.S. University of California, Davis, 1971; Ph.D. University of California, Davis, "The Economic Analysis of Market Control in the California Cling Peach Industry."

Ronald C. Mittelhammer, B.S. Rutgers University, 1972; M.S. Rutgers University, 1974; Ph.D. Washington State University, "The Estimation of Domestic Demand for Salad Vegetables Using a priori Information."

Allen M. Prindle, B.S. Wisconsin State University, 1970; M.S. Purdue University, 1972; Ph.D. Pennsylvania State University, "A Static Equilibrium Model of the U.S. Feed-Livestock Sector."

Shirley A. Pryor, B.A. Smith College, 1965; M.A. Howard University, 1970; M.A. Michigan State University, 1975; Ph.D. Michigan State University, "The Implications of Recent Economic and Policy Changes on Retail and Farm Level Demand for Food Commodities."

Sabry Shehata, B.S. University of Cairo, 1975; M.S. University of Missouri, 1973; Ph.D. University of Hawaii, "Predicting the Market Potential for Fresh Pineapples Using the Survey Approach."

John Chan Sae Tang, B.S. University of Florida, 1971; M.S. University of Florida, 1973; Ph.D. University of Florida, "World Demand for Fresh U.S. Grapefruit: An Application of Seemingly Unrelated Regressions."

Cooperatives and Cooperation

James G. Beierlein, B.S. Rutgers University, 1969; M.S. Rutgers University, 1971; Ph.D. Purdue University, "Optimizing the Capital Structure of Farmer Cooperatives Using A Member Oriented Analysis."

Lionel Williamson, B.S. Alcorn A&M College, 1967; M.S. University of Missouri, 1974; Ph.D. University of Missouri, "The Role of Farmer Cooperatives in Small Farm Development."

Economic Development, Growth and Planning

Moon Suk Ahn, B.Econ. Seoul National University, 1965; M.P.A. Seoul National University, 1967; Ph.D. University of Hawaii, "A Dynamic Modeling Approach to the Determination of the Optimum Port Investment."

Charles Alton, B.A. St. Olaf College, 1965; M.A. University of Kentucky, 1971; Ph.D. University of Kentucky, "The Economics of Dry Season Irrigation in Northeast Thailand."

Jose Alvarez, B.A. University of Florida, 1971; M.S. University of Florida, 1974; Ph.D. University of Florida, "Traditional and Commercial Farm Supply Response in Agricultural Development: The Case for Basic Grains in Guatemala."

J. Raymond Carpenter, B.S. Cornell University, 1959; M.S. University of Toronto, 1962; Ph.D. Colorado State University, "A Critique of Economic Development Planning Since World War II."

Enyinna J. Chuta, B.S. University of Nigeria, 1966; M.S. Michigan State University, 1973; Ph.D. Michigan State University, "Linear Programming Analysis of Small Scale Industries in Sierra Leone."

Bashir M. El-Wifati, B.S. University of Cairo, 1960; M.S. University of Wisconsin, 1966; Ph.D. University of Missouri, "Some Socio-Economic Considerations in the Bedouins' Agricultural Settlement (An Example from Libya)."

Mohammad Faisal, B.S. Dacca University, 1964; M.A. Dacca University, 1965; M.A. Michigan State University, 1976; Ph.D. Michigan State University, "Land and Water Use Planning and Production Response Under Alternative Technologies in Bangladesh—A Programming Approach."

William Arch Gibson, B.Aerospace Eng. Georgia Institute of Technology, 1970; M.B.A. University of California, Berkeley, 1974; Ph.D. University of California, Berkeley, "The Theory of Unequal Exchange: An Empirical Approach."

Anwarul Hoque, B.S. University of Dacca, 1963;

M.S. University of Dacca, 1966; M.A. Michigan State University, 1974; Ph.D. Michigan State University, "A Systems Simulation Approach to Policy Planning and Evaluation in the Context of Integrated Rural Development in Bangladesh."

Young S. Kim, B.S. Seoul National University, 1963; M.A. Michigan State University, 1977; Ph.D. Michigan State University, "Factor Substitutability, Efficiency Growth, and Relative Wage Income Shares in the Korean Agricultural and Manufacturing Sectors: 1955–1974."

Otto G. Konzen, B.S. Federal University, Rio Grande do Sol, 1964; M.S. Federal University, Rio Grande do Sol, 1967; Ph.D. University of Wisconsin, "Effects of a Program to Increase Yields on Farm Organization and Income, A Longitudinal Analysis of Brazilian Farms, 1969 to 1973."

Joao E. Lima, B.S. Universidade Federal, 1969; M.S. Universidade Federal, 1972; Ph.D. Michigan State University, "Projections of the Impacts of Alternative Technologies on Production and Resource Allocation in Southern Brazilian Agriculture, 1970–1985."

Edgardo Ruben Moscardi, A.B. National University of Cuyo, Argentina, 1968; M.S. National School of Agriculture, Mexico, 1971; Ph.D. University of California, Berkeley, "A Behavioral Model for Decision Under Risk Among Small-Holding Farmers."

Richard I. Nellis, Jr., A.B. Cornell University, 1952; M.A. Bucknell University, 1968; Ph.D. Pennsylvania State University, "Determinants of Direct Private Foreign Investment in the Manufacturing Sector of the U.S. Food System."

Epictetus Patalinghug, A.B. University of San Carlos, Philippines, 1969; Ph.D. University of Hawaii, "Education Productivity and Economic Growth—A Two Sector Analysis of Alternative Measures of Quantitative Change."

Teck Y. Pee, B.S. University of Malaya, 1964; M.S. University of Hawaii, 1968; Ph.D. Michigan State University, "Social Returns from Rubber Research in Peninsular Malaysia."

Dibyo Prabowo, M.S. University of the Philippines, 1972; Ph.D. Washington State University, "Water Development and Farm Production Possibilities in the Solo River Basin of Indonesia: A Linear Programming Analysis."

Nelson Rodriguez, B.S. Tennessee Technological University, 1966; Ph.D. University of Tennessee, "Methodology for the Derivation of Scarcity Values of Inputs and Outputs of Venezualan Economy."

Stuart K. Shwedel, B.A. Oakland University, 1968; M.S. Michigan State University, 1973; Ph.D. Michigan State University, "Marketing Problems of Small Farm Agriculture: Case Study of the Costa Rican Potato Market."

Thomas L. Vollrath, B.A. The University of the South; M.S. University of Tennessee, 1973; Ph.D. University of Tennessee, "Credit Needs and Extension Possibilities Among Traditional Rice Farmers in the Northwest Province Cameroon."

Energy

Gary A. Davis, B.S. Montana State University, 1966; M.S. Montana State University, 1968; M.B.A. Michigan State University, 1976; Ph.D. Michigan State University, "A Simulation Study of Decision Strategies for Hog Processing Plants Constrained by Energy Supply Regulations."

Jai Prakash Mishra, B.S.Hons. U.P.A.U. Pantnagar, 1966; M.S. Indian Agricultural Research Institute, 1968; Ph.D. University of Alberta, "Economic Analysis of Energy Use in the Modernization of Indian Agriculture."

Environmental Economics; Conservation

Roy Ronald Carriker, B.S. Eastern Illinois University, 1968; M.S. University of Illinois, 1972; Ph.D. Virginia Polytechnic Institute and State University, "Economic Incentives for Institutional Change: The Case of the Virginia Wetlands Act."

David Freshwater, B.A. Brock University, 1972; M.A. McMaster University, 1973; Ph.D. Michigan State University, "The Linkages Between Individual Use and Public Management of Flood Plains."

Klaus Kurt Frohberg, Dipl. Universitat Hohenheim, 1972; M.S. University of Illinois, 1975; Ph.D. University of Illinois, "Optimal Soil Loss Over Time from a Societal Viewpoint."

Jean Leppen Kinsey, A.B. St. Olaf College, 1963; M.S. University of California, Davis, 1966; Ph.D. University of California, Davis, 1976, "The Effect of Debt on Household Welfare."

Stewart Nelson Smith, B.A. Yale University, 1959; M.S. University of Connecticut, 1974; Ph.D. University of Connecticut, "The Demand for Transferable Development Rights: Theory, Specification, and Estimation Model."

Ruangdej Srivardhana, B.S. Kasetsart University, Bangkok; M.S. University of Wisconsin, 1970; Ph.D. Colorado State University, "Water Uses and an Optimizing Model of Water Pollution Abatement."

Frank Allen Ward, B.S. Colorado State University, 1970; M.S. Colorado State University, 1975; Ph.D. Colorado State University, "The Welfare Effects of a Market Allocation of an Exhaustible Resource."

Fertility

Nan E. Johnson, B.S. Emory University, 1967; Ph.D. Pennsylvania State University, "Farm-Nonfarm Differentials in Fertility: The Effects of Compositional and Sex-Role Factors."

Food and Consumer Economics

Kuang-hsing T. Lin, B.A. Tunghai University, Taiwan, 1967; M.S. University of Connecticut, 1973; Ph.D. University of Connecticut, "A Study of Food Marketing Services and the Relationship to Food Prices."
Jaime Niño, B.S. Javeriana University, Colombia, 1967; Magister, De los Andes University, Colombia, 1971; Ph.D. Stanford University, "Food Consumption Patterns in the United States of America: An Application of the Houthakker and Taylor Dynamic Demand Model."

Human Resource Development

Ahmad Saeed Khan, B.S. West Pakistan Agricultural University, 1968; M.S. West Pakistan Agricultural University, 1970; Ph.D. Oregon State University, "An Economic Analysis of the Demand for Graduate Education."
Adewale F. Mabawonku, B.S. University of Ife, 1969; M.S. University of Ibadan, 1973; M.A. Michigan State University, 1976; Ph.D. Michigan State University, "The Role of Apprenticeship Training in the Small-Scale Industrial Sub-Sector of Western Nigeria."

Industrial Organization; Market Structure

Ronald Cotterill, B.S. Cornell University, 1970; M.S. University of Wisconsin, 1974; Ph.D. University of Wisconsin, "Market Structure, Performance and Market Restructuring in Food Retailing."
Wayne Michael Gauthier, B.S. Louisiana State University, 1965; M.S. Purdue University, 1968; Ph.D. Oklahoma State University, "Economic Analysis of Alternative Approaches to Vertical Coordination in the Beef Production-Marketing System."
Ismael P. Getubig, B.S.Agr. Xavier University, Philippines, 1963; A.B. Xavier University, 1964; M.S. Virginia Polytechnic Institute and State University, 1967; Ph.D. University of Hawaii, "Rice Marketing System in Bicol, Philippines."
Theresa Ann Flaim, A.B. University of Missouri, 1971; M.S. Cornell University, 1974; Ph.D. Cornell University, "Structure of the U.S. Petroleum Industry: Concentration, Vertical Integration and Joint Activities."

Institutions, Private and Public

Josef M. Broder, B.S.A. University of Guelph, 1971; M.S. Michigan State University, 1974; Ph.D. Michigan State University, "The Provision of Court Services: An Inquiry into the Allocation of Opportunities to Rural Communities."
Steven Thomas Buccola, A.B. Saint Mary's College of California, 1966; M.S. University of California, Davis, 1972; Ph.D. University of California, Davis, 1976, "Portfolio Evaluation of Long-Term Marketing Contracts for U.S. Farmer Cooperatives."
Ronald C. Faas, B.S. Iowa State University, 1957; M.S. Iowa State University, 1965; M.A. Michigan State University, 1974; Ph.D. Michigan State University, "The Economics of Budget Constraints, Transactions Costs, and Boundaries on Effective Articulation of Interest Group Demand in Multi-Health Planning Agencies."
Philip G. Favero, B.A. University of Montana, 1965; M.A. University of Montana, 1970; Ph.D. Michigan State University, "The Processes of Collective Action: Small Electric Companies in Michigan."
Duane Arthur Paul, B.S. California Polytechnic State University, San Luis Obispo, 1968; M.S. University of California, Davis, 1969; Ph.D. University of California, Davis, 1976, "Costs and Economies of Scale in Input Marketing Firms with Special Reference to California Retail Farm Machinery Dealerships."

Marketing and Location

David E. Banker, B.S. Clarkson College of Technology, 1969; M.S. South Dakota State University, 1972; Ph.D. Purdue University, "A Model for the Analysis of Alternative Pricing Policies in Federal Milk Marketing Orders."
Armando Victorio Bertranou, Grad. National University of Cuyo, Argentina, 1967; M.S. University of California, Davis, 1969; Ph.D. University of California, Davis, 1976, "The Distribution of Water in the Agricultural Sector of Mendoza."
James Kevin Binkley, B.S. Indiana University, 1968; M.S. Washington State University, 1972; Ph.D. Virginia Polytechnic Institute and State University, "The Effect of Inland Navigation User Charges on Barge Transportation of Wheat."
Bruce Lawrence Dixon, A.B. University of California, Santa Barbara, 1971; M.S. University of California, Davis, 1974; Ph.D. University of California, Davis, 1976, "A Stochastic Control Approach to Harvest Scheduling in a National Forest."
Nathaniel Omatai Okoliko Ejiga, B.S. Ahmadu Bello University, 1969; M.S. Kansas State University, 1972; Ph.D. Cornell University, "Economic Analyses of Storage, Distribution, and Consumption of Cowpeas in Northern Nigeria."
Reza M. Ghanbari, B.S. Junishapoor University, 1972; M.S. Michigan State University, 1977; Ph.D. Michigan State University, "Optimal Allocation of a Renewable Resource: A Bioeconomic Model of the Great Lakes Whitefish Factory."
Frederick Michael Jungman, B.S. Texas A&M University, 1967; M.S. Texas A&M University, 1971; Ph.D. Texas A&M University. "An Analysis of the Market Potential of Peanut Protein Ingredients in Food Processing."
Ernst Lutz, Dipl. Ing.-Agr. Swiss Federal Institute

of Technology, 1973; M.Env.S. Miami University, Ohio, 1974; Ph.D. University of California, Berkeley, "Grain Reserves and International Price Stabilization."

James Cyprian Okuk Nyankori, B.S. Makerere University, 1968; M.S. Ohio State University, 1970; Ph.D. University of Illinois, "Forecasting with a Market Oriented Model: The Spatial and Temporal Price and Allocation Models of the East African Grain Economy."

John M. Patrick, B.S. California State Polytechnic, 1967; M.S. Southern Illinois University, 1973; Ph.D. Michigan State University, "An Economic Analysis of Improving the Viability of Rail Lines: A Michigan Case Study."

Chirmsak Pinthong, B.A. Thammasat University, Thailand, 1972; M.A. Thammasat University, 1974; Ph.D. Stanford University, "A Price Analysis of the Thai Rice Marketing System."

Mohamed Eldermerdash Said Sarhan, B.S.Ag. Alexandria University, Egypt, 1968; M.S. University of California, Davis, 1973; M.A. University of California, Davis, 1974; Ph.D. University of California, Davis, 1976, "An Economic Analysis of Mosquito Abatement in California and the Chemical Industry's Investment in Narrow-spectrum Pesticides."

Robin Neilson Shaw, B.S. Melbourne University, 1969; M.Ad. Monash University, 1974; Ph.D. Cornell University, "Universal Product Code Scanning Systems: The Retail Experience 1974–1976."

Migration

Narong Srisawas, B.S. Kasetsart University, 1963; M.Sc. Nehru Agricultural University, 1966; Ph.D. Pennsylvania State University, "Factors Associated with Internal Migration in Thailand, 1960–1970."

Natural Resource Economics

Kamel S. Al-Ani, B.S. Baghdad University, 1967; M.S. University of California, 1972; Ph.D. Pennsylvania State University, "The Relationship of Water Quality to Residential Property Values."

James C. Chang, B.S. National Chung-Hsing University, 1970; M.S. Tech University, 1973; Ph.D. Oklahoma State University, "The Impact of the McClellan-Kerr Arkansas River Navigation System on the Oklahoma Economy."

Wilmer M. Harper, B.S. Duke University, 1965; M.S. Montana State University, 1969; Ph.D. Oklahoma State University, "The Role of Income in the Perceived Quality of Life of the Rural Populace."

Toshiyuki Kako, B.Ag. Gifu University, Japan, 1969; M.Ag. Kyoto University, Japan, 1971; M.A. University of California, Davis, 1975; Ph.D. University of California, Davis, 1976, "The Estimation of the Transcendental Logarithmic Function and the Decomposition Analysis of Derived Demand for Factor Inputs: The Case of Rice Production in Japan."

Scott Charles Matulich, A.B. California State University, Chico, 1971; M.S. University of California, Davis, 1972; Ph.D. University of California, Davis, 1976, "Economies of Scale of Integrated Dairy Production and Waste Management Systems in the Chino Basin of California."

Loren Lee Parks, A.B. University of California, Santa Barbara, 1964; M.S. University of California, Davis, 1972; Ph.D. University of California, Davis, 1976, "Estimation of Water Production Functions and Farm Demand for Irrigation Water, with Analysis of Alternatives for Increasing the Economic Returns to Water on Chilean Farms."

Carolee Santmyer, B.S. Carnegie-Mellon University, 1957; M.A. University of Pittsburgh, 1961; Ph.D. Washington State University, "An Economic Analysis of Alternative Long-Term Management Programs for Sawlogs, Beef, Elk, and Deer on a Small Portion of the St. Joe National Forest."

Peter Jon van Blokland, B.S. University of Reading, 1963; Dipl. University of West Indies, 1966; M.S. University of Illinois, 1974; Ph.D. University of Illinois, "The Economic Consequences of Hail Suppression and Demand in 1985 on Foodgrains, Feedgrains and Oilmeals in the U.S.A."

Production Economics and Management

Johnson O. Adedeji, B.S. North Carolina A&T State University, 1973; M.S. University of Kentucky, 1974; Ph.D. University of Kentucky, "Use of Polyperiod Programming Techniques in Analyzing Farm Business Growth for Young Farmers: An Ex-Ante Approach."

Richard Haines Bernsten, B.A. American University, 1967; Cert. University of Stockholm, 1970; M.S. University of Illinois, 1973; Ph.D. University of Illinois, "Constraints to Higher Rice Yields in the Philippines."

David Arnold Bessler, B.S. University of Arizona, 1971; M.S. University of Arizona, 1973; Ph.D. University of California, Davis, "Foresight and Inductive Reasoning: Analysis of Expectations on Economic Variables with California Field Crop Farmers."

Michael Thomas Doyle, B.S. Iowa State University, 1967; M.S. University of Nebraska, 1974; Ph.D. University of Nebraska, "A Flexible Management System for Vertical Integration of Feeder Cattle Production and Feedlot Operation."

Daniel Lee Galt, B.S. University of California, 1969; Ph.D. Cornell University, "Economic Weights for Breeding Selection Indices: Empirical Determination of the Importance of Various Pests Affecting Tropical Maize."

Tesfaye Gebremeskel, B.S. Haile Selassie I University, 1968; M.S. Oklahoma State University, 1973;

Ph.D. Texas A&M University, "Cow-Calf Production and Marketing Decisions in East Texas: Application of Risk Constrained Linear Programming and Statistical Decision Theory."

Larry Jonathan Held, B.S. North Dakota State University, 1971; M.S. North Dakota State University, 1973; Ph.D. University of Nebraska, "Growth and Survival of a Wheat Farm Under Selected Financial Conditions: A Simulation Analysis."

Alan S. Kezis, B.S. Rutgers University, 1972; Ph.D. Washington State University, "An Examination of Economies of Size and Net Revenues on Columbia Basin Farms: Implications for Acreage Limitation Policy."

Bernard J. Morzuch, B.A. St. Procopius College, 1970; M.S. Southern Illinois University, 1972; Ph.D. University of Missouri, "Technology and Climatic Effects in Aggregate Production Functions."

Robert M. Ray, B.S. North Carolina State University, 1951; M.S. North Carolina State University, 1962; Ph.D. University of Tennessee, "An Economic Analysis of Swine Production in the Tennessee Valley Watershed of Tennessee."

Miguel Ribon, B.S. Federal University of Vicosa-Brazil, 1962; M.S. Federal University of Vicosa-Brazil, 1966; Ph.D. Oklahoma State University, "Optimal Crop and Dairy Enterprise Selection for Central Oklahoma Dairy Farms."

Vivat Shotelersuk, B.Econ. Thammasat University, Thailand, 1961; M.A. Wayne State University, 1967; Ph.D. University of Hawaii, "Economic Efficiency—A Test for Paddy Farms in Chiang Mai Valley, Northern Thailand."

James Kramer Whittaker, B.S. Oregon State University, 1971; M.S. North Carolina State University, 1973; Ph.D. North Carolina State University, "A Comparison of Alternative Formulations of Econometric Crop Supply Response Models."

Public Policy

Stan G. Daberkow, B.S. University of Nebraska, 1967; M.S. Iowa State University, 1969; Ph.D. University of California, Davis, 1976, "Demand and Location Aspects of Emergency Medical Facilities in Rural Northern California."

Thomas Hoyt Gale, B.S. Cornell University, 1967; M.S. University of Maryland, 1969; Ph.D. University of Wisconsin, "The Determinants of Public Expenditures in Rural Wisconsin Communities."

Ray McFall Lamm, Jr., B.A. North Carolina State University, 1972; M.A. North Carolina State University, 1974; Ph.D. Virginia Polytechnic Institute and State University, "A Policy Analysis of the United States Vegetable Oilseeds, Oils, and Oil Products Industry with Special Emphasis on Optimal Control."

Mahlon G. Lang, B.A. Augustana College, 1969; M.S. South Dakota State University, 1972; Ph.D. Michigan State University, "Collective Bargaining Between Producers and Handlers of Fruits and Vegetables for Processing: Setting Laws, Alternative Rules, and Selected Consequences."

William Gene Lesher, B.S. Purdue University, 1968; M.S. Oregon State University, 1970; Ph.D. Cornell University, "An Analysis of Northeastern Rural Land Use Policies."

Ivarth Palacio, B.S. Universidad Del Valle, Cali, Colombia, 1972; M.S. Oklahoma State University, 1975; Ph.D. Oklahoma State University, "The Impact of European and Latin American Integration on Trade Among Members and with the U.S."

David H. Peterson, B.S. Colorado State University, 1967; M.S. Colorado State University, 1969; Ph.D. University of Wisconsin, "Efficiency and Equity in Pricing Local Public Services: The Case of Wastewater."

Anthony Carleton Zwart, B.S. Lincoln College, 1970; M.S. University of Guelph, 1973; Ph.D. University of Guelph, "An Empirical Analysis of Alternative Stabilization Policies for the World Wheat Sector."

Regional, Rural and Community Development

Roger Beck, B.A. Goshea College, 1967; Ph.D. Pennsylvania State University, "Measurements of Spatially Available Labor for a Rural Area of Pennsylvania."

W. A. N. Brown, B.Agr.S. Lincoln College, New Zealand, 1969; M.Agr.S. Lincoln College, 1972; Ph.D. University of Manitoba, "The Role of Outdoor Recreation in Regional Development: A Study of Hecla Provincial Park."

James W. Dunn, B.S. South Dakota State University, 1972; M.S. South Dakota State University, 1974; Ph.D. Oklahoma State University, "A Mathematical Model for Analysis of Rural Health Care Systems."

Raymundo Eulluran Fonollera, B.S. Central Mindanao University, 1960; M.S. University of the Philippines, 1966; Ph.D. Oregon State University, "The Impacts of Government Market Intervention on Weed Control Technology, Income and Employment: A Case Study of Basic Grain Farms in El Salvador, Central America."

Michel Lee Hiser, B.A. Michigan State University, 1970; M.S. Michigan State University, 1972; Ph.D. Cornell University, "An Interindustry Analysis of Clinton County, New York."

David R. Kelch, B.A. Southern Illinois University, 1968; M.A. Southern Illinois University, 1970; Ph.D. University of Kentucky, "Industrial Location in the Non Metropolitan Communities of Kentucky and Tennessee: 1970–1973."

Bill H. Kinsey, B.A. Washington and Lee University, 1964; A.M. Stanford University, 1968; Ph.D. Stanford University, "Agricultural Technology and Rural Development in the Rainfed Maize Areas of Southeastern Zambia."

Upali Nanayakkara, B.A. University of Ceylon,

1966; M.S. Michigan State University, 1972; M.B.A. Michigan State University, 1976; Ph.D. Michigan State University, "The Economics of Country Fairground Use and the Potentials for Profitable Future Operations Through Use Expansion—A Case Study of the Fairgrounds Project in Emmet County, Michigan."

Alan Osman, B.S. Berea College, 1966; M.A. Harvard University, 1967; Ph.D. Ohio State University, "Benefits and Costs of Specific Manufacturing Firm Locations: Case Study of a Five-County Region in Southeast Ohio."

Donald G. Rozell, B.A. San Diego State College, 1965; M.A. University of Nevada, 1975; Ph.D. Washington State University, "Small Town Finance—A Study of Sixteen Rural Towns in the State of Washington."

George Bryan Wall, B.S. North Carolina State University, 1972; M.E. North Carolina State University, 1973; Ph.D. North Carolina State University, "The Shared Use of Public School Facilities as a Capital Investment Decision Policy."

Karl J. Wise, B.A. Marietta College, 1970; Ph.D. Pennsylvania State University, "Geographical Dimensions in Plant Location Decisions: A Case Study of the Pittsburgh Area."

Michael L. Wise, B.S. Mississippi State University, 1969; Ph.D. Washington State University, "How Communities Choose: A Study of Selected Rural Washington Communities."

Research Methodology

Paul Thomas Dyke, B.S. Oklahoma State University, 1963; M.S. Oklahoma State University, 1966; Ph.D. Oregon State University, "An Econometric Structure for Cost Functions with Application to Municipal Water."

William David Mulkey, B.T.M. Auburn University, 1968; M.A. Clemson University, 1971; Ph.D. Clemson University, "Interregional Input-Output Matrices from Secondary Data."

William Bruce Traill, B.S. University of Glasgow, 1970; Ph.D. Cornell University, "Incorporation of Risk Variables in Econometric Supply Response Models."

Robert D. Weaver, B.A. Carlton College, 1971; M.S. University of Wisconsin, 1975; Ph.D. University of Wisconsin, "The Theory and Measurement of Provisional Agricultural Production Decisions."

Sector and Subsector Analysis

Waroon Garnjana-Goonchorn, B.Econ. Thammasart University, Thailand, 1969; M.Econ. Thammasart University, 1971; A.M. Duke University, 1972; Ph.D. University of Connecticut, "A Study of Intersectoral Income Transfers in the U.S. Using Modified Duymovic-Farrish Model Emphasizing Investment Structures."

Thomas H. Spreen, B.S. Purdue University, 1973; M.S. Purdue University, 1974; Ph.D. Purdue University, "An Application of Capital Theory in a Recursive Linear Programming Model of the Cattle Sub-sector of Guyana."

Annie On Lai Yuen, B.S. University of Hong Kong, 1971; M.A. University of Wisconsin, 1974; Ph.D. University of Wisconsin, "Dynamic Modeling in an Agricultural Subsector: An Analytic-Empirical Approach."

Socioeconomic Research

Judith Banister, B.A. Swarthmore College, 1965; Ph.D. Stanford University, "The Current Vital Rates and Population Size of the People's Republic of China and its Provinces."

Habib T. Fatoo, B.S. Florida A&M University, 1972; M.A. Michigan State University, 1975; Ph.D. Michigan State University, "Macro Economic Analysis of Output, Employment and Migration in Sierra Leone."

George Milton Kreps, B.S. Manchester College, 1955; B.D. Bethany Biblical Seminary, 1963; M.A. Ohio State University, 1972; Ph.D. Ohio State University, "A Study of Crime in Rural Ohio: The Relationship Between Ecological Factors and a Rural Crime Index."

Joseph Lissa Tommy, B.S. North Carolina A&T, 1969; M.S. Ohio State University, 1972; Ph.D. Ohio State University, "Socioeconomic Determinants and Policy Implications of the Decision to Migrate: An Empirical Rural-Urban Migration Study."

Taxes, Taxation, and Rural Appraisal

Mohammed Ariff, B.S. University of Malaya, 1970; Ph.D. Pennsylvania State University, "Tax Burden on Rubber, Coconut and Pineapple Smallholders in Johore, Malaysia."

James Eugene Epperson, B.S. Auburn University, 1967; M.S. Auburn University, 1969; Ph.D. Mississippi State University, "Implication of Changes in Tax Laws for the Intergeneration Transfer of the Farm Firm in Mississippi."

Hernan L. Hurtado, Grad. Catholic University of Chile, 1970; M.A. University of California, Davis, 1974; Ph.D. University of California, Davis, 1976, "EC Import for Grains: Some Implications of the Common Agricultural Policy on US Imports."

Panayotis Athanasios Konandreas, Grad. National Technical University of Athens, 1969; M.S. University of California, Davis, 1972; M.A. University of California, Davis, 1974; Ph.D. University of California, Davis, 1976, "An Econometric Analysis of U.S. Grain Exports with Policy Implications of Price Stabilization."

Ralph Thomas Schotzko, B.S. University of Idaho, 1967; M.S. University of Idaho, 1972; Ph.D. Oregon State University, "An Analysis of the Effects

of Social Security Taxes on Resource Allocation in the U.S. Farm Sector."

Technological Change

James Larry Deaton, B.A. North Carolina State University, 1971; M.E. North Carolina State University, 1973; Ph.D. North Carolina State University, "The Admission and Diffusion of the Combined Harvestor-Threshor in the United States: A Study in Economic History."

George Landis Greaser, B.S. Pennsylvania State University, 1971; M.S. Pennsylvania State University, 1972; Ph.D. Virginia Polytechnic Institute and State University, "Economic Feasibility of Using Weather-Altering Technology on Apple Orchards in Virginia, 1977."

Ramiro Orozco, B.S. Universidad Del Valle, Cali, Colombia, 1967; M.S. Oklahoma State University, 1970; Ph.D. Oklahoma State University, "Sources of Agricultural Production and Productivity in Colombian Agriculture."

Chandrashekhar Govind Ranade, B.S. University of Poona, 1966; M.S. Indian Statistical Institute, 1969; Ph.D. Cornell University, "Distribution of Benefits from New Agricultural Technologies: A Study at Farm Level."

Trade

Keith James Collins, B.S. Villanova University, 1969; M.A. University of Connecticut, 1973; Ph.D. North Carolina State University, "An Economic Analysis of Export Competition in the World Coarse Grain Market: A Short-Run Constant Elasticity of Substitution Approach."

Chaiwat Konjing, B.S. Kasetsart University, 1965; M.S. Michigan State University, 1970; Ph.D. University of Minnesota, "Thailand's Maize Export Agreement Policy: An Economic Analysis."

John David Spriggs, B.A. University of New England, 1971; M.S. University of Minnesota, 1976; Ph.D. University of Minnesota, "An Econometric Analysis of the Factors Affecting Australia's Grain Exports."

Gary James Wells, B.A. University of North Carolina, Asheville, 1973; M.E. North Carolina State University, 1974; Ph.D. North Carolina State University, "The Impact on Wheat Import Patterns from the Entrance of the United Kingdom into the European Economic Community."

Fisheries Economics

Tommy Mack Jones, B.S. Auburn University, 1963; M.B.A. Georgia Southern College, 1971; Ph.D. Clemson University, "A Productivity and Profitability Analysis of the South Carolina Double-Rig Shrimp Fishery: A Case Study of a Specialized One Year Class Fishery."

Land Economics

Richard Dunford, B.A. University of Missouri; M.A. University of Wisconsin, 1974; Ph.D. University of Wisconsin, "An Economic Analysis of Changes in the Ownership and Use of Rural Real Estate in Southwestern Wisconsin."

Ph.D. Recipients by Institution

University of Alberta

Jai Prakash Mishra

University of California, Berkeley

Antonio Garcia-Ferrer
William Arch Gibson
Ernst Lutz
Abraham Melamed
Edgardo Ruben Moscardi

University of California, Davis

Armando Victorio Bertranou (1976)
David Arnold Bessler
Jon Alan Brandt
Steven Thomas Buccola (1976)
Wadsworth Scott Cauchois, Jr.
Stan G. Daberkow (1976)
Bruce Lawrence Dixon (1976)
Hernan L. Hurtado (1976)
Toshiyuki Kako (1976)
Jean Leppen Kinsey (1976)
Panayotis Athanasios Konandreas (1976)
Scott Charles Matulich (1976)
Dwight Douglas Minami
Loren Lee Parks (1976)
Duane Arthur Paul (1976)
Mohamed Eldemerdash Said Sarhan (1976)

Clemson University

Tommy Mack Jones
William David Mulkey

Colorado State University

J. Raymond Carpenter
Ruangdej Srivardhana
Frank Allen Ward

University of Connecticut

Waroon Garnjana-Goonchorn
Kuang-hsing T. Lin
Stewart Nelson Smith

Cornell University

Nathaniel Omatai Okoliko Ejiga
Theresa Ann Flaim
Daniel Lee Galt
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Obituaries

Henry Ernest Erdman

Henry Ernest Erdman, one of the early entrants to the field of agricultural economics, died 19 September 1977, in his 92nd year. He was born 6 November 1884, on a South Dakota grain and livestock farm, attended South Dakota State College, and there received the B.S. degree in dairy science in 1912. After three years in the dairy industry, he enrolled at the University of Wisconsin. He studied with such pioneers as Taylor, Hibbard, and Ely, and, in 1920, was awarded a Ph.D. degree.

Erdman taught at Ohio State University 1917–21, then joined USDA to direct studies of marketing costs of agricultural products. Milk and dairy products were his special interest. A year later Erdman moved to the University of California, Berkeley, where he served with distinction until his retirement as professor of agricultural economics in 1952.

Erdman remained active in research after his retirement. At Berkeley, his primary interest was in marketing institutions, particularly agricultural cooperatives. His academic work was marked by insight and rigor, and he was noted for his warmth, kindness, goodwill, and integrity.

Among numerous honors, Henry Erdman was recognized by the American Marketing Association as a "pioneer in marketing" and received the Paul D. Converse Award for "Contributions to Science in Marketing." He served as president of the American Farm Economic Association in 1929.

Erdman is survived by two daughters, Mrs. James Lyons, Linden, California, and Mrs. Margaret McKillop, Grants Pass, Oregon, and by five grandchildren.

Morris Evans

Morris Evans was born in Linden, Iowa, 15 September 1891, and died on 6 November 1976, in Toronto, Canada.

Evans attended a four-room elementary school in Iowa, then finished his grade school education in a one-room country school in Kansas after his parents moved to a farm north of Topeka. He spent a year at Baker Academy, 1908–09, six years at Kansas State Agricultural College—interrupted by two years in World War I, and one year at the University of Illinois.

In 1920, Evans became associated with Kansas State University, and remained on that staff until April 1935, when he joined the U.S. Department of Agriculture as manager of a federal land purchase project. In 1936, he was transferred to the regional office of the Resettlement Administration, Amarillo, Texas. That office later became the Farmers Home Administration.

Another reorganization separated Evans' work from FHA, transferring it to the Bureau of Agricultural Economics of USDA. Evans was in charge of the land economics section, and later of flood control investigations in parts of Kansas, Colorado, Oklahoma, Texas, and New Mexico.

Evans transferred to the Berkeley office of BAE in 1941. In August 1942, he joined the Department of Agricultural Economics at New Mexico College of Agriculture and Mechanical Arts (now New Mexico State University). In addition to his teaching duties, Evans did field research in dry land areas of New Mexico and dairy studies in eastern New Mexico and in the Rio Grande valley.

Evans retired because of ill health in January 1958, and later moved to Toronto, Canada, to live near his son, Paul. He died in Toronto.

Arthur Ross Milner

Arthur Ross Milner, professor emeritus, Ohio State University, died on 22 November 1977. Milner was born in Waterford, Ohio, in 1907. He received his bachelor's degree in agriculture from Ohio State University in 1929, and his M.S. degree in agricultural economics from Cornell University, in 1949.

Following his graduation from Ohio State in 1929, Milner was employed with the agricultural extension service in Ohio, serving as extension agent in Ashtabula County until 1954. He then joined the faculty of the Department of Agricultural Economics and Rural Sociology at Ohio State University, as an assistant professor. He was promoted to associate professor in 1957, and to full professor in 1962. Although his earlier specialty was farm management, he taught grain marketing and authored several publications in that field. His text, *Grain Marketing,* was published in 1970. He also became a recognized authority in the field of agricultural cooperatives.

Milner was not only a dedicated member of his profession, but also a distinguished member of his community, as well. He was active in both church and community affairs. He was a member of AAEA, the Agricultural Marketing Forum, Gamma Sigma Delta, Alpha Zeta, and Epsilon Sigma Phi.

He is survived by his wife, Catherine, and two children.

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American Agricultural Economics Association

Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
—supporting an employment registry for agricultural economists in cooperation with the U.S. Department of Labor.

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Articles

Effects of Market-Share and Antimerger Policies on the Fluid Milk-Processing Industry

Richard L. Kilmer and David E. Hahn

The effects of merger restriction policies and market-share restriction policies on the structure of the Ohio fluid milk-processing industry are compared and contrasted within an intertemporal production distribution model. Individual firm size constraints are predicated on the transition probabilities of a Markov Chain. Merger restrictions are found to be less disruptive of industry structure. However, market share is a more effective tool for controlling concentration. The appropriate combination of merger-market share policies must be based on an analysis of market performance on a market-by-market basis.

Key words: dairy, market performance, market share, Markov Chain, merger, separable programming.

As government agencies address the problem of maintaining adequate market performance in the fluid milk industry, information is needed on the effect of policy instruments on industry structure. Only limited information is currently available on the differences in structural effects over time between market share and merger restrictions or among various levels of market share restrictions. Mueller, Hamm, and Cook studied the dairy-processing industry to determine the impact of the Federal Trade Commission's merger policy that commenced in 1956. The findings support the contention that public policy can significantly influence an industry's structure and in the process maintain competition. Kloth-Blakely and Bobst-Waananen used a modeling approach to determine the impact of market share restrictions on the structure of the fluid milk-processing industry. They found that market share restrictions increased marketing cost.

The objective of this study is to compare and contrast the effects of merger restriction policies and market share restriction policies on the structure of the Ohio fluid milk-processing industry. Within an intertemporal production distribution model, individual firm size constraints are predicated on the transition probabilities of a Markov Chain. Market share and merger restriction policies are imposed on the model and the effects contrasted among alternative policies.

The dairy industry has a local market orientation. Mueller, Hamm, and Cook (p. 68) found that 87% of fluid milk sales by sixty-nine firms were made within 50 miles of plants owned. Regional and national multiplant firms generally have one plant within a local market area (Parker, pp. 64–72). When firms in a local market do merge, only one plant is used to process fluid milk in order to realize existing plant scale economies. Policy research must be directed at the local market level where single-plant firm operations exist. In this article, firms are defined as single-plant operations.

Richard L. Kilmer is an assistant professor, Food and Resource Economics Department, University of Florida; David E. Hahn is associate professor at Ohio State University and the Ohio Agricultural Research and Development Center.

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The Economic Model

The model is an extension of the Kloth-Blakely model which extended the production-distribution model formulation of Martin

by incorporating size economies. These models were an extension of the Stollsteimer model and are solved with a separable programming algorithm. They determine the optimum number, size, and location of processing firms which minimize processing, assembly, and/or distribution costs. However, these models have implicit assumptions that are restrictive: (*a*) all firms have equal growth capability; (*b*) a firm may operate at volumes that vary from that of a profit maximizer but are consistent with minimizing industry cost; (*c*) current firm size has no effect on future industry organization; and (*d*) time-related variables do not affect industry organization.

The assumptions underlying the model for this study are less restrictive. In particular: (*a*) Firms do not possess equal growth capability. Individual firm size in any given time period is limited to a size range predicated on fluid milk processing firms of similar size. The range is determined from the transition probabilities of a Markov Chain, equations (4), (5), (9), (10), (11). (*b*) Firms are profit maximizers and possess a certain degree of market power (price is greater than marginal cost). Therefore, firms are not permitted to operate in the decreasing returns-to-scale portion of the aggregate long-run average cost curve (the sum of processing costs and distribution costs). (*c*) Current firm size affects future industry organization. Each processing firm in 1972 was assigned its actual 1972 size in order to compute individual firm size for 1977, equations (9), (10), (11). In future time periods, the individual firm size computed in the model is used in determining firm size range. (*d*) Time-related variables affect industry organization. The variables are adjusted between each time period. The specific time-related variables are demand for fluid milk products, equation (7), and size range for individual firms, equations (4) and (5).

The mathematical notation of the model is as follows:

$$(1) \quad \text{Minimize } TC^t = \sum_j^{s^t} f(X_{j.}^t) + \sum_j^{s^t} \sum_k^{m} R_{jk} X_{jk}^t,$$

subject to:

$$(2) \quad f(X_{j.}^t) = \sum_h^{\mu} B_h^t \, Y_h \, A_h,$$

$$(3) \quad X_{j.}^t = \sum_h^{\mu} B_h^t \, Y_h,$$

$$(4) \quad X_{j.}^t \leq E^t(X_{j.}) + \alpha \, \sigma_j^t,$$

$$(5) \quad X_{j.}^t \geq E^t(X_{j.}) - \alpha \, \sigma_j^t,$$

$$(6) \quad C \leq X_{j.}^t \leq E,$$

$$(7) \quad \sum_j X_{jk}^t = D_k^t, \text{ and}$$

$$(8) \quad X_{jk}^t \leq \gamma \, D_k^t,$$

where TC^t is total processing and distribution costs in time t; s^t is number of potential processing firms in time t; $X_{j.}^t$ is number of quarts of milk processed by firm j in time t; $f(X_{j.}^t)$, total processing cost of firm j in time t; m, number of demand areas; R_{jk}, cost in dollars per quart of transporting fluid milk products by truck from firm j to the wholesale customer in demand area k; X_{jk}^t, quarts of fluid products transported by truck from processing firm j to the wholesale customer in demand area k; μ, number of linear segments employed to approximate the nonlinear total processing cost curve ($\mu = 10$); B_h^t, facilitating variable for the introduction of the characteristics of a nonlinear function into a linear-programming algorithm;[1] Y_h, the differential between two firm volumes;[2] A_h, marginal processing cost in dollars per quart associated with the quarts in segment Y_h; $E^t(X_{j.})$, expected size of firm j in time t; α, a nonnegative scalar used in model validation and imposition of antimerger restrictions; σ_j^t, the standard deviation around the expected size of firm j in time t; C, the minimum processing firm size; E, the maximum processing firm size; D_k^t, the demand for fluid milk products in demand area k in time t; γ, a nonnegative scalar with a maximum value of 1 used when market share restrictions are imposed on the model.

The model minimizes fluid milk-processing and distribution costs, equation (1), for each time period (five-year intervals), subject to constraints that introduce economies of scale, equations (2) and (3), introduces a size range for each firm, equations (4) and (5), limits minimum and maximum firm size, equation (6), insures supply equals demand for all con-

---

[1] Values of B_h^t are from zero to 1 inclusive. When $0 \leq B_1^t \leq 1$, $B_2 = , \ldots , = B_{10} = 0$. When $B_1 = 1, 0 \leq B_2 \leq 1, B_3 = , \ldots , B_{10} = 0$.

[2] The potential firm volumes are divided into ten unique (nonoverlapping but contiguous) not necessarily uniform segments. $\sum_h Y_h = 524{,}200$ maximum firm size.

sumption areas, equation (7), and permits variation of the market share controlled by any one firm, equation (8). Demand and firm size ranges are revised for each time period.

The individual firm size range, equations (4) and (5), in time t is based on the transition probabilities of a Markov Chain process. The derivation of the range is

$$(9) \qquad E^t(X_{j.}) = \sum_b^r P_{ab}A_b,$$

where $E^t(X_{j.})$ is expected size of firm j in time t; P_{ab} is probability of a firm moving from size category a in time $t - 1$ to size category b in time t; r is number of firm size categories; A_b is midpoint of size category b (when $b = a$, the actual size of firm j in time $t - 1$ is used).

The standard deviation of the expected size of firm j in time t is computed as follows:

$$(10) \qquad \sigma_j{}^t = \left\{ \sum_b^r [A_b - E^t(X_{j.})]^2 P_{ab} \right\}^{\frac{1}{2}}.$$

The individual firm size range [equations (4), (5)] for each time period is determined as

$$(11) \quad X_{j.}{}^t \lesseqgtr E^t(X_{j.}) \pm \alpha\sigma_j{}^t = \sum_b^r P_{ab}A_b \pm \alpha \left\{ \sum_b^r [A_b - E^t(X_{j.})]^2 P_{ab} \right\}^{\frac{1}{2}}.$$

Merger restrictions are introduced through α, equations (4), (5). As α is decreased, the maximum size potential for a firm is decreased, equation (4). To impose an antimerger policy on an individual firm or a subset of the entire firm population, the value of α is decreased (table 1, policy D). This is consistent with the hypothesis that firms will grow at a slower rate with merger restrictions when the only recourse for growth is through competition in the marketplace. This hypothesis implies that mergers tend to increase market concentration (Scherer, p. 122).

Table 1. Parametric Values of Market Share and Merger Restrictions for Alternative Government Policy Instruments

Government Policy Alternatives		Parameter Values	
Policy Designation	Government Policy (all firms affected)	γ	α
A	None	1.0	.65
B	20% market share	.2	.65
C	10% market share	.1	.65
D	No mergers permitted	1.0	.50[a]

[a] Estimated value. See text.

A precise parameter value representing the decrease in firm growth caused by merger restrictions is not available. An arbitrary value of .5 was assigned α in Model D. During model validation, α for Model A was established as .65 on the assumption that it should be greater than the α of Model D. This is consistent with the hypothesis that firms will grow at a slower rate with merger restrictions when the only recourse for growth is through competition in the marketplace. The selected value of α will allow the effects of merger policy, in general, to be observed.

Market-share restrictions are introduced through γ, equation (8). The maximum percentage of any demand area k allowed to be served by any firm j may be varied from 100 to zero by changing γ. The value of 20% (table 1, policy B) was chosen because of its significance in antitrust policy guidelines. Justice Department guidelines indicate that mergers will likely be challenged when four-firm concentration is 75% or more in any market (Federal Register). A 10% market share restriction (table 1, policy C) was chosen because of its significance in the literature which suggests that when four-firm concentration is less than 40%, the competitive norm is approximated (Bain, Mueller, and Stigler).

When using a separable programming algorithm, a global optimum is assured in a minimization problem if the objective function is a convex function and the constraints form a convex set. The sufficient conditions for a global optimum are violated by equation (2); therefore, the results from this model can be assumed to be a local optimum only (Kilmer). Even when the conditions for a global optimum are violated, the separable programming technique is recognized as producing acceptable solutions (Blakely and Kloth, Kloth and Blakely, Holland and Baritelle).

Data

The State of Ohio was assumed to be a closed economy (no exports or imports). With the eighty-eight counties treated as demand areas, the maximum market radius for each firm is assumed to be 100 miles from the processing firm to the county seat of each demand area. The base year for costs, processing firm numbers, firm locations, and initial firm size was 1972.

The county demand for fluid milk products was the product of county population projections (for 1972 and 5-year intervals thereafter) and projected per capita demand for fluid milk products (Jacobson et al.).

The long-run average cost function was based on cost data from Cobia-Babb and Devino. The cost data was updated to 1972 through the use of indexes. Least squares regression was used to obtain the following function:

$$\text{Log } AC = \text{Log } (-.628) - .139 \log V$$
$$(.257) \quad (.019) \qquad R^2 = .57$$
$$n = 40$$

where $\text{Log } AC$ = Log of dollars per quart, $\text{Log } V$ = Log of plant volume specified in quarts, and the estimated standard errors for the coefficients are included in parentheses.

Distribution costs include those costs from the processing firm to the wholesale customer or, in home delivery, to the final customer. Included are fixed and variable truck costs, labor costs for loading and unloading cases from a truck, truck refrigeration costs, route supervisor costs, substation costs, and administrative costs associated with wholesale distribution. Business taxes, advertising, and profit are not included. The fluid milk products were assumed to be moved in a 65,000 pound gross vehicle weight tractor rig hauling 14,000 quarts per load from the processing firm to the county seat of each county. Wholesale and home delivery customers were served from the county seat.

The distribution cost function was based on the work of Connor and was indexed to reflect 1972 prices and the prevalent price level in Ohio. The function includes a cost for transferring packaged fluid milk products from the processing firm to the county seat of the demand area plus a cost associated with "in-county" distribution. Total distribution costs per quart for each processing plant-demand area combination were determined from the following function:

$$C = .054 + .00003M, \tag{12}$$

where C is dollars per quart and M is round trip mileage.

Model Validation

The model was validated by comparing the values of two variables among the observed 1977 values, a Markov Chain projection, and policy A. The variables were: (*a*) the total firm numbers remaining in the industry after each time period, and (*b*) the size distribution of firms remaining in the solution after each time period. Average distribution and average processing cost per quart were compared with empirical data. In 1977, policy A approximated the observed firm numbers in Ohio (74). Furthermore, policy A approximated the

Table 2. The Firm Size Distribution of the Ohio Fluid Milk-Processing Industry, 1977–97

	Year										
	1977			1982		1987		1992		1997	
Size Category[a]	Observed	Markov Model	Policy A	Markov Model	Policy A	Markov Model	Policy A	Markov Model	Policy A	Markov Model	Policy A
	(Firm Numbers)										
1	26	16	4	8	10	4	10	2	13	0	3
2	5	4	10	3	10	3	11	2	3	2	1
3	20	17	3	14	12	11	6	9	1	7	1
4	5	12	29	9	12	7	5	5	6	4	1
5	4	10	1	8	0	7	3	6	0	5	4
6	1	2	0	2	0	2	0	2	0	2	0
7	4	6	15	5	14	5	13	4	15	4	15
8	3	3	4	4	2	4	0	4	0	4	0
9	6	4	4	5	6	5	8	6	8	6	8
Total firms	74	74	70	58	66	48	56	40	46	34	33

[a] Processing firm volume is represented by the following categories:

Category	Quarts/Day	Category	Quarts/Day	Category	Quarts/Day
1	0– 5,349	4	23,948–47,931	7	80,244–106,991
2	5,350–14,265	5	47,932–71,897	8	106,992–178,318
3	14,266–23,947	6	71,898–80,243	9	178,319–524,200

number of firms remaining in the industry in 1977 and 1997, but there were greater differences in 1982 and 1987 (table 2) when compared with the results generated by the Markov model.

The size distribution generated by policy A was understated in the lower categories while the middle and top categories were overstated in 1977 when compared with the observed size distribution. However, when policy A was compared with the Markov model over several time periods, the size distributions are overestimated in the lower three and top three size categories, with the middle three categories being underestimated (table 2). Thus, policy A over time has a higher percentage of firms in the low and top categories which is consistent with the observed 1977 distribution.

Finally, per quart processing and distribution costs generated by policy A (when compared with empirical data) approximate observed costs with processing cost being slightly overestimated (table 3).

Results

The number of firms remaining in the industry over time would be approximately the same for each alternative policy through 1982 (table 4). By 1987, the 10% market share and the merger restriction policies begin to restrict the number of firms leaving the industry. Between 1977 and 1987, the no-restraint policy and 20% market share restriction policy would result in a decrease of fourteen and fifteen firms while the 10% market-share restriction and merger restriction policies would result in a decrease of only five and four firms, respectively.

Because fewer firms would remain in the industry for the no-restraint policy and 20% market share policy, the average firm size would be larger. During the ten-year period between 1977 and 1987, the average firm size under a no-restraint policy would increase by

Table 3. Fluid Milk Product Processing and Distribution Costs for Selected Years

Year	Distribution Cost (¢/qt.)	Processing Cost (¢/qt.)
1972 (observed)[a]	4.8	3.7
1973 (observed)[a]	5.4	4.6
1977 (computed)	5.3	4.7

[a] *Marketing and Transportation Situation*, United States Department of Agriculture, Washington, D.C., November 1974, p. 35. These costs do not include business taxes or profit.

Table 4. Size Distribution of Fluid Milk Processing Firms, Ohio, 1977–87

Category	Policy A Firms (no.)	Policy A Firms (%)	Policy B Firms (no.)	Policy B Firms (%)	Policy C Firms (no.)	Policy C Firms (%)	Policy D Firms (no.)	Policy D Firms (%)
1977								
A[a]	17	24.3	20	28.2	9	12.7	8	11.4
B[a]	30	42.9	29	40.8	37	52.1	37	52.9
C[a]	23	32.8	22	31.0	25	35.2	25	35.7
Total	70	—	71	—	71	—	70	—
1982								
A	32	48.5	25	37.9	19	27.6	29	41.4
B	12	18.2	19	28.8	25	36.2	18	25.7
C	22	33.3	22	33.3	25	36.2	23	32.9
Total	66	—	66	—	69	—	70	—
1987								
A	27	48.2	17	30.4	13	19.7	26	39.4
B	8	14.3	17	30.4	28	42.4	32	48.5
C	21	37.5	22	39.2	25	37.9	8	12.1
Total	56	—	56	—	66	—	66	—

[a] Processing firm volume size represented by the following categories:

Category	Quarts/day
A	0– 23,947
B	23,948– 80,243
C	80,244–524,200

more than 18,000 quarts per day to a total capacity of 84,964 quarts. During this period average firm size would increase to 83,474 quarts for the 20% restriction and 72,091 for both the 10% restriction and the merger restriction policy.

Between 1977 and 1987, the 20% and 10% market-share restriction alternatives would permit the existence of more firms processing more than 80,000 quarts daily as compared to the merger restriction policy (table 4). The market-share restriction alternatives would encourage firm growth in the large size category (firms processing more than 80,000 quarts daily).

The market shares for the top four and top eight firms would increase for each of the four policy alternatives between 1977 and 1987 (table 5). The 10% and 20% market share increases less than the no-restraint policy or merger-restriction policy for the top four and top eight firms.

The 20% and 10% market-share restriction policies would yield six and eleven firms supplying a demand area in 1987 compared with

Table 5. Market Shares of the Top Four and Top Eight Fluid Milk Processing Firms, Ohio, 1977–87

	Policy A	Policy B	Policy C	Policy D
	Four Firms Market Share			
1977	29.5%	29.5%	24.1%	28.0%
1982	38.2	35.1	25.6	34.4
1987	44.1	35.4	26.0	41.1
	Eight Firms Market Share			
1977	42.6%	42.6%	37.2%	40.5%
1982	53.7	49.9	40.0	48.7
1987	62.3	53.2	40.5	56.0

Table 6. Fluid Milk Processing Firms with a Processing Capacity of More Than 40,000 Quarts Per Day, Ohio, 1977–87

	1977		1982		1987	
	Number of Firms	%	Number of Firms	%	Number of Firms	%
Policy A	41	58.6	30	45.5	29	51.8
Policy B	44	62.0	37	56.1	40	70.0
Policy C	45	63.4	41	59.4	48	72.7
Policy D	46	65.7	35	50.0	31	47.0

two for a no-restraint policy. The demand areas supplied by a fluid processing firm in 1987 will be three for a no-restraint, compared to 9, 14, and 14 for the 20% and 10% market share and the antimerger policies.

Previous studies indicate that firms which have the capacity for at least 40,000 quarts daily can process efficiently (Parker, p. 78). By 1987, the no-restraint policy would result in fewer efficient firms (both in absolute numbers as well as a percentage of all firms) as compared to the 10% and 20% market share policy and about the same number as the merger restriction policy (table 6)

Average processing costs would decrease between 1977 and 1987 for each of the four policy alternatives (table 7). Distribution costs would remain constant or increase during this same time period except for the merger restriction policy. The decreases in processing costs are larger than the changes in distribution costs for each of the policy alternatives. A 10% market share restraint would increase costs to the consumer by .6¢ per quart and an antimerger policy would increase costs by .15¢ per quart as compared to the use of no-policy instruments in 1987.

Conclusions And Implications

On the basis of this analysis, it is evident that the fluid milk-processing industry will become increasingly concentrated if instruments of antitrust policy are not utilized. The maintenance of moderate levels of concentration through the use of policy instruments would increase costs to the consumer by .15¢ per quart if an antimerger policy was adopted and by .6¢ per quart if a 10% market share restraint were adopted. These relatively minor

Table 7. Average Processing Costs and Average Distribution Costs for Fluid Milk Processing Firms, Ohio, 1977–87

Cost of Item	Policy A	Policy B	Policy C	Policy D
	(cost/qt.)			
	1977			
Average processing	$.0468	$.0468	$.0475	$.0472
Average distribution	.0525	.0541	.0554	.0526
Average aggregate	.0993	.1009	.1029	.0998
	1982			
Average processing	$.0451	$.0456	$.0470	$.0463
Average distribution	.0526	.0543	.0555	.0525
Average aggregate	.0977	.0999	.1025	.0988
	1987			
Average processing	$.0435	$.0447	$.0467	$.0453
Average distribution	.0526	.0545	.0555	.0524
Average aggregate	.0961	.0992	.1022	.0977

per quart cost increases must be evaluated with respect to other dimensions of market performance. Manchester found that concentration in fluid milk processing was positively correlated with deteriorating allocative efficiency and negatively correlated with innovativeness. A policy dilemma remains: are decreases in technical efficiency caused by employing policy instruments offset by improvements in allocative efficiency and innovativeness? The recent review, revision, and continuance of merger restrictions in fluid milk processing suggests an affirmative answer.

At least three policy alternatives exist: (*a*) continue current antimerger policy, (*b*) use only market share policy, (*c*) combine market share and antimerger policy.

The current antimerger policy is designed to limit selectively the growth of processing capacity for large firms and at the same time nurture the middle tier. The premise is that a strong middle tier will insure adequate competition even with the existing degree of concentration. However, antimerger policy limits the growth of firm processing capacity in the short term only. In the longer term, a firm through internal expansion can grow to a size equal to a firm that grew through merger. Thus, a combination of merger-market share restrictions may be appropriate in the longer run.

Conceptually, market share restriction is a more effective tool for resolving excessive concentration than is an antimerger policy. A 10% market share constraint when compared with merger (*a*) increases the percentage of firms processing more than 24,000 quarts daily, (*b*) maintains the market share of the top four and eight firms at a lower level than that of merger, (*c*) increases the percentage of competitively sized firms (> 40,000 quarts daily), and (*d*) increases the number of competitors in each market. These effects are accomplished at a cost to the consumer of only 0.45¢ more per quart than the cost associated with the antimerger policy. At the same time, market share maintains the number of firms in the industry and average firm size at approximately the same level as merger. The operational mechanism associated with implementing a market-share restriction policy could be facilitated through the market administrator. If market restrictions were violated, new firms would be required to enter the demand area in order to meet demand.

For many markets, there is merit in considering a combination of merger and market share policies. As a large firm expands its market radius in order to maintain or increase its daily volume, market expansion by acquisition may be attempted in lieu of internal growth through competition in the market place. The smaller firms need the opportunity to merge with small and medium firms in order to attain a competitive size. A permissive merger policy to small and middle tier firms and a restrictive policy toward large firms would seem appropriate. A market share restriction on large firms may be needed to insure an adequate market for competitively sized small and medium firms.

The structural diversity of fluid milk markets precludes a universal merger-market share policy for the fluid milk industry. Measures of market concentration on a national, or even regional, level do not provide a relevant basis for evaluating performance of local fluid milk markets. The appropriate combination of merger-market share policies must be based on an analysis of market performances on a market-by-market basis.

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A Pooled Cross-Section Time Series Model of Coupon Promotions

Ronald W. Ward and James E. Davis

Coupons influence consumption through both a price-discounting and advertising effect. These effects have been measured using consumer panel data on the retail consumption of frozen orange juice. Two cross-sectional time series models, estimated with a variance components procedure, show the effectiveness of coupons, assuming habit and nonhabit persistence along with consumer demographics. The response from coupons is shown to be conditioned by the container prices as well as with the characteristics of the redeemer.

Key words: advertising, consumer demand, coupons, cross-sections and time series, orange juice.

Advertising is playing an increasing role in the marketing of agricultural products and the literature on advertising theory is beginning to reflect this importance to agricultural trade (Hochman, Regev, Ward; Thompson and Eiler; Ward). Surprisingly, a number of specific media for informing or stimulating the consumer have received minimal analysis by economists. In particular, the economic theory of coupons and its applications have been all but ignored in the studies of advertising effectiveness. Yet, coupons represent a multimillion dollar industry with the majority of the programs related directly to food consumption (Henderson and Brown, Nielson, A.C. Nielson Co.). Recognizing the deficiency in both conceptual and applied research relating to the use of coupons, this paper will set forth some basic economic principles of coupons and then report the empirical results from a cross-sectional time series study of national coupon programs for promoting frozen concentrated orange juice.

Coupon programs are implemented by first having a major coupon drop through mass distribution via a number of different media (Schwartz). Once the drop is made consumers redeem the coupons over the life of the program. Ward and Davis have shown the patterns of coupon redemption given various media and drop levels for coupon programs intended to promote frozen orange concentrate retail sales. Given that C coupons are dropped at some time, Ward and Davis' model shows the maximum redemption that ultimately will be realized. The time path and rate of redemption indicates how and when the promotional effort reaches the consumer. Once redemption occurs, then the basic question of its economic effect must be addressed.

Since redemptions represent individual uses of coupons, changes in individual consumption behavior must be related to the coupons redeemed. Further, the effectiveness of coupons may differ depending on the characteristics of the redeemer. Given the importance of the redeemer to an understanding of the economics of coupons, subsequent analysis is based on cross-sections of consumers with their consumption data recorded over time. Procedures for pooling cross-sectional and time series data are used in estimating the coupon model.

In the first and second sections we will develop the coupon theory and estimation procedures. In the remaining section we will provide a direct measure of the effect of coupons on the retail consumption of frozen concentrated orange juice. Monthly panel data from 9,231 households reporting up to forty-eight months are used for the analysis. The Market Research Corporation of America (MRCA) maintains a national panel of consumers who keep a weekly diary of their purchases. The panel participants are selected by MRCA to

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provide a representative sample of the consumer demographics in the United States. All data relating to the purchases of frozen concentrated orange juice, as reported by the panel, have been used in this study and the weekly diary from each panelist was aggregated to a monthly basis.

Coupon Theory

Houthakker and Taylor have argued that demand is dynamic where a consumer response to changes in prices, income, or other exogeneous factors is distributed over time. Studies of the effects of advertising on consumer demand have suggested that carryover effects (i.e., lagged advertising effects) are likely but may differ with the marketing instrument used (Ward). In the case of coupons, any carryover is expected to be minimal primarily because coupons are designed to require a purchasing response in order to use the income or, equivalently, the price discounting value of the coupon. While mass media advertising is intended to inform and entice the consumer by changing preferences, coupons are intended primarily to convey a deal to the consumer.

Recognizing the potential for habit formation as outlined by Houthakker and Taylor, the effects of coupons on consumer i can be illustrated, where q_{it}^* is the expected consumer response to prices (p), coupons (c) and other factors (z), and $\dot{q}_{it}$ is a change in consumption from period $t-1$. The actual response may differ from the expected response due to previous consumption habits. Hence, one model specification may be

$$(1) \qquad q_{it}^* = H(p_{it}, c_{it}, z_{it}), \text{ and}$$

$$(2) \qquad \dot{q}_{it} = G(q_{it}^*, q_{i(t-1)}).$$

From (1) and (2) it follows that the current level of consumption can be derived as

$$(3) \qquad q_{it} = F(p_{it}, c_{it}, z_{it}, q_{i(t-1)}).$$

The extent of the habit persistence is shown where

$$\frac{\partial q_{it}}{\partial q_{i(t-1)}} = F_\theta,$$

letting θ be the parameter measuring the extent of habit persistence. If $F_\theta = 1$, complete rigidity to change would be indicated, while $0 < F_\theta < 1$ suggests some degree of rigidity. Finally, $F_\theta = 0$ implies $q_{it}^* = q_{it}$. While the habit persistence can be measured, of equal importance to the current problem is the effect of coupons.

Coupons are expected to influence consumption through both their redemptive value and informational effects. The redemptive value represents reductions in the purchasing price to the consumer since the coupon generally gives cents off the purchasing price, i.e., the price effect. The informational value should yield additional increases in consumption primarily because the coupon is a tangible reminder of the availability of a particular product, i.e., the informational effect. If the price effect equals the total effect, then coupons would be no different from an on-package price cut to the consumer.

Using equation (3) and assuming that p is the price consumers face prior to using the coupon, then the total coupon effect is $dq = F_c dc$, and F_c is the shift in the consumer's demand curve. The actual price discount resulting from c depends on the level of q, where[1]

$$(4) \qquad p^* = p - (c/q).$$

Further, changes in the level of c influence the purchase price (p^*) such that

$$(5) \qquad dp^* = \left\{\frac{c}{q^2} F_c - \frac{1}{q}\right\} dc.$$

Assuming that a change in the purchase price generates the same response as a change in the container price

$$\left(i.e., \frac{\partial q}{\partial p^*} = \frac{\partial q}{\partial p}\right),$$

the components of $\{F_c\}\ dc$ holding the container price fixed follows as

$$(6) \qquad dq = F_p^*\ dp^* + A_c\ dc,$$

[1] The purchase price has been distinguished from the container price in order to measure both the price and informational components of a coupon. The alternative of using the purchase price when measuring the demand elasticity is possible but more cumbersome to the analysis. Also, an interaction between the coupon and price level necessitates using the container price in the model. Consumers are generally not aware of the container price when first exposed to the coupon and, thus react to the container price once drawn to the point-of-purchase via the coupon. Note in (4) that the price effect of a coupon depends on the total purchases to which the coupons are redeemed against.

Prices were defined in cents while coupons were measured in dollars. The effect of coupons on price in equation (4) must be adjusted by 100 to compensate for this difference. These variables were expressed in different units for estimation convenience used later in a nonlinear model.

letting A_c be the informational or advertising effect from coupons. Substituting (5) into (6) and equating (6) to $\{F_c\}\, dc$, then A_c can be measured, where

$$(7)\quad \left\{F_c - F_p{}^* \left[\frac{c}{q^2} F_c - \frac{1}{q}\right]\right\} dc = A_c\, dc.$$

Equation (7) shows the additional consumption resulting from using coupons after the price effect has been netted out. For the couponer, the size of A_c becomes critical to the evaluation of the usefulness of this marketing instrument.

While (7) shows the responses to c for a given container price, it is likely that the effectiveness of c will be influenced by the actual container price. Coupons draw the consumer to the point-of-purchase, yet if the container price is extremely high, the marginal response to a level of c may be less than with a lower price since, for the same dq, the consumer's expenditures would be greater for the higher p (Telser, p. 90). Hence, $F_c > 0$ but $F_{cp} < 0$. Furthermore, $F_{cc} \gtreqless 0$ depending on the final specification of (3).

The effect of habit persistence will also depend on the final model specification. Using a nonlinear model similar to Houthakker, Verleger, and Sheehan's, the effects of habit are easily shown. Let

$$(8)\quad q_{it}^* = p_{it}^{\xi_1}\, c_{it}^{\xi_2} \exp^{\xi_0}, \text{ and}$$

$$(9)\quad \log(q_{it}/q_{i(t-1)}) = \log(q_{it}^*/q_{i(t-1)})^{\theta},$$

then

$$(10)\quad q_{it} = p_{it}^{\theta\xi_1}\, c_{it}^{\theta\xi_2}\, q_{i(t-1)}^{(1-\theta)} \exp^{\theta\xi_0}.$$

If the habit persistence is strong, then $\lim_{\theta\to 0} q_{it} = q_{i(t-1)}$ and coupons have no effect on consumption. If $\theta = 1$, there is no habit persistence and the effectiveness of coupons is determined according to ξ_2.

Variance Component Model

The coupon model in (10) is based on cross-sections of consumer households reporting over time. The maximum number of time periods is relatively short ($T_i \leq 48$ months); and, while T_i may differ among households, there are no missing values within the reporting periods for each T_i. Changes in MRCAs consumer panel and the length of time a panel member reports has led to different T_i's. Further, the habit persistence model suggests that there is resistance to random changes from one time period to another. In contrast, the number of households is large (9,231 cross-sections) and considerable variation among these cross-sections can be expected.

Given the values of T_i and i, the error in model (10) is assumed to be

$$(11)\quad \omega_{it} = \mu_i + \nu_{it},$$

where μ_i is that component of ω_{it} due to random difference in households, and ν_{it} is a general variation over i and t. Interaction terms and dummy variables can be used to account for nonrandom differences in slopes and systematic changes over time. Growth trend and seasonality variables are to be included in the model to account for intercept changes over time. As a general rule, it is much easier to account for time series versus cross-sectional differences. The inclusion of these variables implies that the error over time is reduced to zero and equation (11) is the appropriate error specification (Wallace and Hussain, p. 57; Maddala, p. 327).

With the usual assumptions of the variance component model, it follows that the variance in equation (11) is

$$(12)\quad \sigma^2 = \sigma_u^2 + \sigma_v^2.$$

The ratio $\rho = \sigma_u^2/\sigma^2$ shows that portion of the total variation resulting from differences in households. While a number of alternative methods for estimating ρ have been outlined, a maximum likelihood procedure similar to that discussed by Maddala (p. 345) and altered to accommodate different T_i will be used in this study.

Empirical Coupon Model

Preliminary estimation indicated that the coupon model for frozen concentrated orange juice is nonlinear and a number of demographic variables proved useful for explaining differences in households. The structure of the coupon model corresponding to equations (3) and (10) follows in (13).

$$(13)\quad q_{it} = \{p_{it}\}^{\theta\xi_1}\, \{c_{it}\}^{\theta\xi_2}\, \{q_{i(t-1)}\}^{(1-\theta)} \exp^{(\xi_0+\mu_i+\nu_{it})},$$

letting

$$\xi_1 = \sum_{j=0}^{5} \gamma_j z_{jit} + \sum_{k=1}^{4} \beta_k r_{kit},$$

$$\xi_2 = \sum_{j=0}^{5} \lambda_j z_{jit} + \phi \log(p_{it}),$$

$$\xi_0 = \sum_{j=0}^{7} \alpha_j z_{jit} + \Gamma \log(I_{it}),$$

and q_{it} is ounces of single-strength equivalent FCOJ purchased by consumer i in month t where twenty-four single-strength ounces is one 6-ounce can of FCOJ, p_{it} is the container price reported by consumer i for month t (¢/oz.), c_{it} is the total value of all coupons redeemed by consumer i in month t (\$), I_{it} is income level (1, high; 2, med.-high; 3, mod.-low; and 4, low), z_0 is constant ($z_0 = 1$), z_1 is race (0, caucasian; 1, other), z_2 is children (1, children present; 0, no children), z_3 is education (1, college; 0, less than college), z_4 is age (1, under forty; 0, otherwise), z_5 is age (1, greater than sixty; 0, otherwise), z_6 is monthly time periods (1, 2, 3, . . . , beginning with January 1972 through December 1975 for forty-eight months), z_7 is seasonality variable, r_1 is region (1, Northeast; 0, otherwise), r_2 is region (1, North Central; 0, otherwise), r_3 is region (1, Mountain-Southwest; 0, otherwise), r_4 is region (1, Pacific; 0, otherwise), and r_5 is region (southern region deleted for estimation of dummies).

Of particular importance to the analysis is the value of ξ_2 in equation (13), since ξ_2 represents the total elasticity with respect to coupons. ξ_2 depends on both demographic characteristics, the container price, and is weighted by θ. A priori, the effects of demographics can not be hypothesized, i.e., β_j, λ_j, γ_j, $\alpha_j \gtreqless 0$. In contrast, as prices increase, the stimulant from a given level of coupons should decrease because the consumer must pay more for the increased consumption, i.e., $\phi < 0$.

Equation (13) is estimated with and without the habit persistence model using panel data of 9,231 households reporting intermittently over a forty-eight month period with a total of 127,329 observations. The estimates of the concentrated likelihood function for both models show that approximately 45% to 50% of the variation can be attributed to random differences among households.

The generalized least squares estimates for both models are reported in table 1. For the habit persistence model, the total number of observations are decreased to 118,098, since one observation for each household is lost with the inclusion of $q_{i(t-1)}$. The habit persistence parameter $(1-\theta)$ is statistically significant, yet its numerical value suggests that habit persistence plays a very small role in the explanation of current consumption. Under these circumstances, $q_{it}^* \simeq q_{it}$ from equations (1) and (3) and the importance of the habit formation is minimal. As evident from the table, the parameters estimated for both the habit and no-habit models show only minor differences. The inclusion of the demographic variables delineates differences among cross-sections. Nevertheless, the error component model shows the importance of correcting for random difference among households.

A number of the demographics were analyzed for their effects as slope and intercept shifters. Race was not statistically significant in explaining differences in the levels of demand. Both the presence of children in the household and the educational level of the household's principal purchaser indicated positive effects on consumption. The younger and older households showed a greater level of consumption relative to the middleage household. The seasonal and trend variables indicated a significant seasonality deviating about a positive growth trend. Finally, the discrete income variables lead to positive increases in consumption (note that the income parameter is negative since the measure of income was with one being the highest level).

Coupon Effectiveness

The total effect of the coupons redeemed (c) and the ratio of the advertising effect to the total are of primary interest. Using the estimates from table 1, both the total coupon and advertising effects can be shown along with the specific effects of those demographic characteristics of the consumer. From equations (5) and (13), it follows that $F_c = \xi_2(q/c)$ and $F_p^* = \{\xi_1 + \phi \log(c)\} (q/p)$. The information or advertising effect can then be calculated relative to the total coupon effect using either the habit and no-habit model with the difference being the inclusion of θ.

$$(14) \qquad R_c = A_c/F_c, \text{ or}$$

$$R_c = 1 - \frac{\theta\{\xi_1 + \phi \log(c)\}}{\theta\xi_2} \{\theta\xi_2 - 1\}(c/pq).$$

Table 1. Coupon Model for Habit and No-habit Assumptions [see equation (13)]

	No-Habit Persistence ($\theta = 1$)		Habit Persistence ($0 < \theta < 1$)	
	Parameter	Standard Deviation	Parameter	Standard Deviation
Constant	4.87748	.03438	4.93808	.03518
Race	.05741	.09484	.14429	.09807
Children	.13585	.03935	.13384	.04034
Education	.06167	.03207	.08128	.03275
Age 1 (under 40)	.06166	.03893	.06490	.03988
Age 2 (over 60)	.09554	.04269	.10939	.04349
Time	.00382	.00013	.00339	.00014
Seasonality	.01460	.00232	.01385	.00243
Income	−.06129	.00720	−.06293	.00745
Price	−1.40022	.07197	−1.44061	.07503
Price * Northeast region	.53932	.02745	.56412	.02900
Price * North Central	.07536	.02971	.12138	.03133
Price * Southwest	.15867	.03847	.14739	.04080
Price * Pacific	.25401	.03586	.25424	.03805
Price * race	−.04964	.03967	−.04990	.04144
Price * children	.19819	.02247	.19999	.02365
Price * education	.02725	.01798	.02178	.01876
Price * age 1	−.09255	.02230	−.09007	.02345
Price * age 2	.07250	.02388	.07516	.02492
Coupons[a]	.03849	.00715	.03446	.00732
Coupons * race	−.00091	.02008	.01207	.02074
Coupons * children	−.00677	.00849	−.00628	.00871
Coupons * education	.00448	.00676	.00916	.00691
Coupons * age 1	.02818	.00830	.02796	.00850
Coupons * age 2	.03966	.00918	.04223	.00936
Coupons * price	−.14885	.01450	−.15302	.01508
Lagged consumption	—	—	.00018	.00003
Observations	127,329		118,098	
ρ	.50		.45	
Number of households	9,231		9,231	
Concentrate likelihood	123,108.5		114,823.7	
Variance of the estimate (σ_n^2)	.6474		.5854	

[a] Since coupons are expressed in logs, $c = .01$ where no coupons are used ($\log c = -4.606$). C represents the total coupons redeemed and does not represent the face value of any one coupon.

Equation (14) is nonlinear in all variables and it is somewhat cumbersome to derive the effect of changes in these variables on the advertising and total effects. Alternatively, it is relatively easy to simulate the effects under varying levels of the independent variables. The empirical value of (14) should show directly the extent of the informational effect coupons have on consumers.

The total and informational effects of coupons can be analyzed for specific demographic characteristics and for the average consumer. Calculating the average from the nonlinear model yields a geometric rather than a simple mean. Hence, the average must be converted to an arithmetic mean in order to reference the average consumer.[2] Using the average proves most useful when aggregating over households. Also, household responses to coupons and prices are more readily illustrated when the possible combinations of demographic effects are averaged.

Average Coupon Effect

The graphical counterpart to table 1 (no-habit persistence) is shown in figure 1, where the demand represents the average consumer

[2] The geometric mean (GM) is calculated using the following values for each group of dummies referenced in (13):

$I = 2.0339$	$z_4 = .392$	$r_1 = .309$
$z_1 = .058$	$z_5 = .253$	$r_2 = .305$
$z_2 = .487$	$z_6 = 24$	$r_3 = .106$
$z_3 = .431$	$z_7 = .014$	$r_4 = .127$

Given the variance of the log normal distribution estimated in table 1, the arithmetic mean (AM) is approximated over the demographics where (Klein, p. 328)

$$AM = GMe^{\sigma_n^2/2} \text{ and } \sigma_n^2 = .6434.$$

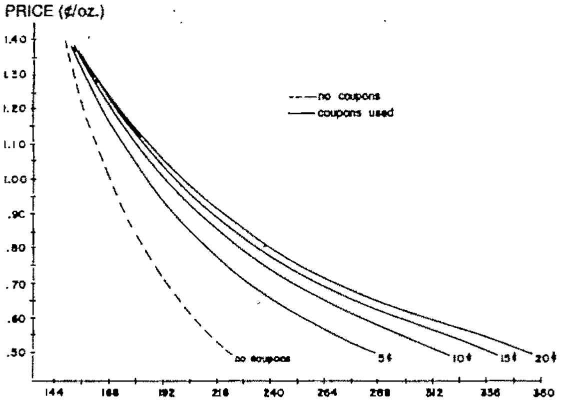

Figure 1. Coupon effect on the average household demand relationship using the no-habit persistence model from table 1

using the mean values for all variables other than prices and coupons. Both the nonlinear nature of demand and the interaction of prices and coupons are clearly evident. Consumers facing higher prices respond less to the use of coupons in terms of additional consumption. At the lowest price (.5¢), monthly consumption increases by 65 ounces with 5.0¢ worth of coupons. Note that the worth of the coupons represents the aggregate value of the coupons redeemed and not the denomination of each coupon. As the price increases to 0.6¢, coupons are approximately 76% as effective as at the lower price. The remaining percentages of effectiveness decline as prices increase. Note that once price reaches 1.4¢ per ounce, coupons are nearly ineffective for the average relationship. Coupons are assumed to generate consumption and not storage. While the MRCA data do not distinguish between purchases and actual consumption, one indirect way to test for this would be to include a lagged value of c in the no-habit model. A negative parameter suggests some storage. Applying this proxy procedure indicated a negative parameter; however, the resulting model showed over 90% of the coupon effect to be actual consumption and not storage. While this procedure is ad hoc and cannot be applied to the habit model, we conclude that the results in table 1 are satisfactory models of the coupon effectiveness. The parameters in both models with and without the lag coupon were nearly identical and the storage component is small relative to the total coupon effect.

This alternative specification has not been included in the paper but is available upon request to the authors.

The interaction between coupons and prices usually works to the advantage of the concentrate industry because during periods of higher prices there is generally less incentive to promote sales. Lower prices reflect greater supplies and a greater need for promotions, and at these lower prices coupons tend to be more effective.

Coupons also show a declining marginal rate of return within the price range shown in figure 1. Using a price of 0.5¢ in figure 1, coupons totalling 20¢ led to 137.4 ounces increase in consumption. Approximately 47% of this gain could have been achieved with 5.0¢ worth of coupons; 72% would have resulted with 10¢; and nearly 88% of the gain could have been achieved with coupons equalling 15¢.

The same relationships shown in figure 1 have been calculated with the habit persistence equation from table 1, and little numerical difference in the levels of consumption were evident. Also, the models in table 1 were estimated without the demographics and a comparison of the average consumer response in figure 1 to that of the nondemographic models gave nearly identical results.

Advertising Effect

The responses from figure 1 indicate that consumers can be stimulated to increase their consumption via the use of coupons. This increase results from a change in the purchasing price as well as from the addition of new information. Using equation (14) the informational component of the total response can be measured.

Figure 2 reports the ratio of the informational or advertising effect to the total coupon response shown in figure 1. First, considering the consumption gains realized from 5.0¢ worth of coupons at a container price of 0.6¢, 87% of the gain in consumption was directly due to the informational stimulant. For higher prices, the total response declined and the informational impact decreased relative to the total effect. Given higher prices, the model clearly shows that it is more difficult to stimulate the consumer using new information. This relationship is especially important to couponers, since during periods of rising prices the coupon program generally costs more to implement and the program becomes a less effective marketing tool.

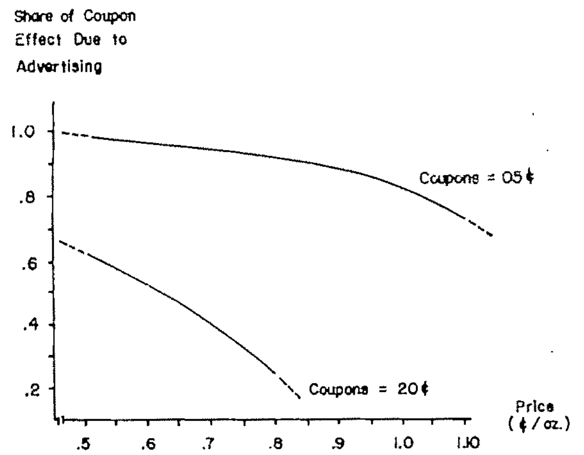

Figure 2. The ratio of the advertising to the total coupon effect

The lower graph in figure 2 shows the advertising ratio for coupons totalling 20¢ per month. The declining stimulant with higher prices is still evident. In addition, for the same price, the advertising effect relative to the total has declined. While total gains increase with an increase in the total value of coupons used, that portion of the gains resulting from simply giving the consumer a price discount has increased. In this sense, the couponer uses the larger value of coupons as a price-cutting device, because most of the informational effect could have been achieved with a smaller total value of coupons. Again, this ratio becomes especially important to the couponer since the coupon value and the intensity of the coupon drop can lead to a mechanism for price discounting with secondary informational effects. Likewise, if waste occurs, then both the consumer and couponer are ultimately worse off.

Demographic Effect

As shown in table 1, a number of demographics were included in the coupon model. Of these, the redeemer's age proved to be significant in having both a direct and indirect effect on coupon effectiveness. Since the over-forty and under-sixty age groups were used as the base, the effectiveness of coupons used by the two remaining age groups relative to this base is readily calculated. The relative difference in responses to coupons redeemed for the age groups relative to the base are compared using $dq = F_c\, dc$ for each age group.

(15a) $$\frac{dq|<40}{dq|\,40\text{–}60} = 1.0636\, c^{.0282}\, p^{.0926}, \text{ and}$$

(15b) $$\frac{dq|>60}{dq|\,40\text{–}60} = 1.1003\, c^{.0397}\, p^{.0725}.$$

Table 2 shows the values of (15a) and (15b) assuming various levels for coupons and prices. For the lower total value of coupons (i.e., coupons totalling 5¢), the younger consumers respond more to the level of coupons, while older consumers respond less. Given larger values of coupons, the effectiveness of both age groups increases relative to the base group. As prices increase, the model further shows that the marginal responses to coupons become less for the younger consumer group. During periods of higher prices, the under-40 group becomes increasingly more difficult to stimulate relative to the older consumers. In contrast, the older consumers become somewhat more responsive relative to the 40–60 group.

While the other demographics included in equation (13) have not been analyzed in detail in this article, it is clear that having an analytical understanding of the consumer profile is essential to the successful implementation of coupon programs.

Net Expenditures

The retail expenditures net of the value of the coupons should vary with both the amount of coupons and the retail container prices. The difference in net expenditures relative to that with no coupons are recorded in figure 3. Note that for the lower prices, coupons generate a net gain in retail expenditures where, for ex-

Table 2. Coupon Effectiveness Relative to the 40–60 Age Group

	05¢ coupons		20¢ coupons	
Price (¢/oz.)	Under 40 yrs.	Over 60 yrs.	Under 40 yrs.	Over 60 yrs.
.6	1.0248	.9415	1.0656	.9947
.8	.9979	.9613	1.0376	1.0156
1.0	.9775	.9770	1.0164	1.0322
1.2	.9611	.9900	.9994	1.0459

Note: Values correspond to the gain in consumption for that age group relative to that realized by the base group. See variables z_4 and z_5.

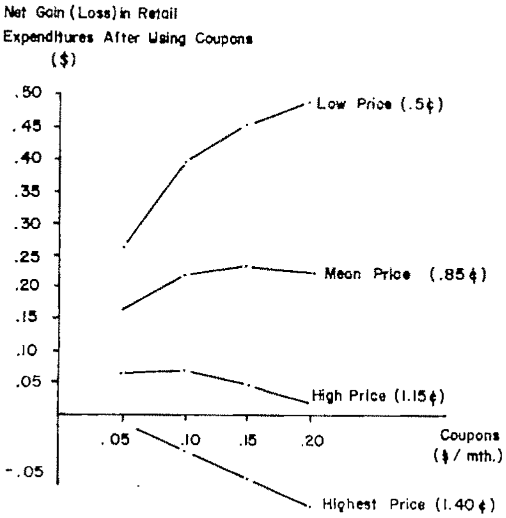

Figure 3. Net gains (losses) in retail expenditures resulting from coupons

ample, 20¢ worth of coupons increased retail expenditures by nearly 68¢, giving a net of 48¢. At the mean price, net expenditures actually declined with coupons valued greater than 15¢. Finally, for the highest price in figure 3, the cost of the coupons exceeds any increase in retail expenditures resulting from using coupons.

Figure 3, like the prior figures, applies to the average consumer and, hence, may differ when specific demographics such as age are considered. If coupon drops could be directed to selected demographic targets, the models could be easily adjusted to estimate the consumers response.

Conclusion

The empirical results from the study of coupons promoting frozen concentrate show coupons to be an effective tool for informing the consumer. While the coupon parameters are for a specific commodity, the conceptual framework should be applicable to a broad number of commodities. The demographic differences, the declining marginal returns to coupons, and the advertising effect are likely general to many food products. This particular couponed product is unique in that the product is generic; whereas, a number of similar programs are brand-oriented. The analysis does not address the incidence of brand switching resulting from coupon drops.

The demand model in conjunction with the coupon redemption model can be used to evaluate the projected impact of various coupon programs for the concentrate industry. Assessment of such programs prior to implementation can reduce cost and economic waste resulting from excessive drops. From a theoretical perspective, the coupon model delineates the effect of prices from informational stimulants.

Historical trends indicate that coupons will continue to be used to promote food products and may well be one of the major ways for stimulating consumers to enter certain areas of food stores more frequently. Further, evidence of cooperative couponing between retailers and wholesalers and use of joint ventures to coupon noncompetitive products suggest structural changes that result directly from an effort to inform the consumer. Considerable research needs to be completed on relating the success of advertising programs with that of changing market structures in agriculture.

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The Potential Impact of Changes in Income Distribution on Food Demand and Human Nutrition

Per Pinstrup-Andersen and Elizabeth Caicedo

A procedure is developed to estimate nutritional and food demand implications of changing consumer income distribution. Findings from an empirical application to the population of Cali, Colombia, suggest that changes in income distribution can effectively improve human nutrition, even in the absence of food supply expansions. These same changes also have a large impact on the demand for individual food commodities. In societies where significant changes occur in income distribution, commodity demand projections preferably should be based on individual stratum rather than on average estimates of price and income elasticities.

Key words: demand analysis, developing countries, income distribution, malnutrition, public policy.

Malnutrition continues to be one of the most serious problems of human health and welfare in many developing countries. Its magnitude and implications for child mortality, either by itself or in combination with various diseases, as well as its impact on human capital formation, labor productivity, and general social welfare are documented and discussed by Berg; Call and Longhurst; Kallen; Pan American Health Organization; Reutlinger and Selowsky; Scrimshaw and Behar; Weisberg, Reese, and McDonald; and others, and will not be discussed here.

Malnutrition is caused by a variety of food supply and demand-related factors, as well as factors determining nutrient utilization in the human body. If any one of these highly interrelated factors can be singled out as the most important, it probably would be that of low incomes among certain groups of the population. Average national figures for many developing countries show little or no nutritional deficiencies. However, when such figures are disaggregated by consumer-income group, severe deficiencies are frequently observed. Hence, in these countries the problem of nutritional deficiencies is one of unequal distribution of available nutrients rather than absolute scarcity.

Low income consumers usually spend a very large proportion of their total income on food, and incomes are frequently insufficient to cover nutritional requirements, even if the total income were spent on food and a minimum cost diet were adopted.[1] Under such circumstances, expansions in food supply without simultaneous increases in consumer incomes will contribute relatively little to the elimination of malnutrition (Pinstrup-Andersen, de Londoño, Hoover).[2] Likewise, increases in consumer incomes while maintaining current income distribution might have limited impact on the nutritional status because a large portion of the additional demand would be consumed by higher income groups (Pinstrup-Andersen, de Londoño, Hoover).

On the other hand, since elasticities tend to be inversely correlated with income levels,

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[1] For example, in a recent study, the Colombian Planning Department found that, at current incomes, 41% of the Colombian population would be unable to meet minimum nutritional requirements, even from a minimum cost diet in which no consideration was given to consumer preferences (Departamento Nacional de Planeación).

[2] While rationing and forced distribution offer an obvious solution to this problem and has, in fact, been attempted under certain totalitarian regimes, this article is focused on societies where household demands are determined by individual preferences and purchasing power.

transfer of incomes from higher to lower income consumers might provide an effective vehicle for increasing consumption among lower income groups that are nutrient deficient, without an adverse nutritional effect among higher income groups.

Sound public policies aimed at the reduction or elimination of malnutrition through the marketplace must be based on reliable quantitative information regarding the impact of changes in income distribution on food demand and nutritional status. While the quantitative relationship between income redistribution and food demand has been estimated in a number of studies, including FAO, Machicado, Mujica and Martinez, and Saleh and Sisler, studies of the relationship between income redistribution and human nutrition are scarce, and additional work is needed to adapt methodology and provide empirical estimates useful for policy making (Reutlinger and Selowsky).

The objectives of the study reported here are (*a*) to suggest an approach for estimating the nutritional impact of changes in income distribution, (*b*) to provide empirical evidence of this relationship for the city of Cali, Colombia, and (*c*) to examine the implications of these estimates for public policy in the areas of income distribution, human nutrition, agricultural research, and other supply-related issues.

The nutritional impact is estimated under two assumptions regarding food supply: first, a fixed supply and, second, an unlimited supply at current prices. The former may be interpreted as a situation where the supply elasticity is zero, while the latter might represent either a perfectly elastic supply or a situation where the shifts in the demand curve caused by changes in income distribution are matched by equal shifts in the supply curve. The required shifts in the supply curve are estimated to provide guidelines for supply-focused policies and agricultural research. Policies aimed at changing income distribution are analyzed in two groups: those resulting in increasing incomes for low income consumers, maintaining other incomes constant; and those resulting in transfer of incomes from higher to lower income consumers, maintaining total incomes constant. No attempts are made to identify specific policy measures within these groups.

The present study supplements previous research on the nutritional impact of expanded food supply (Pinstrup-Andersen, de Londoño, Hoover) and the distribution of benefits from new agricultural technology among consumer income strata (Pinstrup-Andersen) by analyzing the nutritional impact of changing income distribution rather than changing food supply. The remainder of the discussion is divided into four parts. First, the model is described; then follows a brief description of data requirements and sample characteristics; the last two parts present the empirical findings and a discussion of the policy implications.

The Model

The model is based on neoclassical demand theory. A comparative static analysis is carried out to determine the market equilibrium before and after a change in consumer incomes and/or their distribution. Free market price formation is assumed. The total population of consumers is divided into five strata on the basis of income level. It is assumed that all consumers are facing the same market and the same price for any one of the commodities. Using a comparative analysis, the impact of alternative changes in consumer income distribution on calorie and protein intake is estimated. The model utilizes price and income elasticities of demand by income stratum. Procedures for estimating these elasticities were previously reported (Pinstrup-Andersen, de Londoño, Hoover) and will not be repeated here.

The income elasticity of calorie and protein intake was estimated for each income stratum. This elasticity concept expresses the change in calorie or protein intake as a function of changes in incomes of a particular stratum and is estimated as follows:

$$e_{c(m)} = \frac{\sum_{i=1}^{A} c_i q_{i(m)} E_{i(m)}}{\sum_{i=1}^{A} c_i q_{i(m)}}, \text{ and}$$

$$e_{pr(m)} = \frac{\sum_{i=1}^{A} pr_i q_{i(m)} E_{i(m)}}{\sum_{i=1}^{A} pr_i q_{i(m)}},$$

where $e_{c(m)}$ is income elasticity of calorie intake, $e_{pr(m)}$ is income elasticity of protein in-

take, A is the number of commodities, c_i is per unit calorie content, pr_i is per unit protein content, $q_{i(m)}$ is quantity consumed, and $E_{i(m)}$ is income elasticity of demand. Subscripts i and m denote commodity and stratum, respectively. These elasticity measures were used to estimate the impact of changes in the income distribution on calorie and protein intake under the assumption of perfectly elastic supply.

The model used in the case of a fixed supply requires additional elaboration because all strata are competing for a fixed quantity of each commodity. Hence, changing the relative purchasing power among strata will introduce a series of adjustments in the quantity consumed by all strata until a new equilibrium is reached. Those adjustments and the resulting new equilibrium in prices and quantities consumed by each stratum will depend on the price and income elasticities for the various strata, the initial incomes and quantities consumed by strata, and the magnitude and structure of the change in purchasing power.

When additional incomes are obtained by stratum m, the demand curve for commodities with positive income elasticities of demand will shift to the right and consumers will purchase more of that commodity. If the supply is perfectly elastic, or if the supply curve is shifted in the same magnitude, prices would remain constant and no quantity adjustments would be made in the other strata. However, if the supply elasticity is positive and not perfectly elastic, prices will be bid up by the expanded demand by stratum m, and the other strata will adjust quantities demanded correspondingly. Stratum m would, in turn, adjust quantities demanded according to the new prices and the adjustments would continue and would—if the system is convergent—result in a new equilibrium. Similar adjustments will take place if income is transferred from one stratum to another.

Let the initial market equilibrium price for commodity i be p_i^0: then the new equilibrium price p_i^1 after shifts in the supply and/or demand curves is estimated as (Pinstrup-Andersen and Tweeten)

$$(1) \qquad p_i^1 = p_i^0 \left[1 - \frac{\Delta S_i - \Delta D_i}{(e_{si} - e_i)Q_i^0}\right],$$

where ΔS_i is the horizontal shift in the supply curve of commodity i, ΔD_i is the horizontal shift in demand curve of commodity i, e_{si} is the price elasticity of supply for commodity i, e_i is the market price elasticity of demand for commodity i, and Q_i^0 is the initial equilibrium quantity of commodity i.

Since the supply is fixed and perfectly inelastic, $\Delta S_i = e_{si} = 0$, i.e., the total quantity consumed of commodity i remains constant. ΔD_i is the sum of the horizontal shifts in stratum demand curves of n strata for commodity i $\left(\sum_{m=1}^{n} \Delta d_{i(m)}\right) \cdot \Delta d_{i(m)}$, in turn, is estimated on the basis of the change in incomes of stratum $m(\Delta Y_{(m)})$, the income elasticity of demand for commodity i in stratum $m(E_{i(m)})$, and the initial quantity of commodity i consumed by stratum $m(q_{i(m)}^0)$. Hence,

$$(2) \qquad \Delta D_i = \sum_{m=1}^{n} b_{(m)} E_{i(m)} q_i^0{}_{(m)},$$

where $b_{(m)} = \left(\frac{\Delta Y}{Y}\right)_m$,

$$(3) \qquad p_i^1 = p_i^0 \left[1 - \frac{\sum_{m=1}^{n} b_m E_{i(m)} q_i^0{}_{(m)}}{e_i Q_i^0}\right],$$

and n is the number of strata.

The quantity adjustments within each stratum are estimated as the sum of the changes in the quantity demanded due to income changes which bring about shifts in the demand curve, and price changes reflected in movements along the demand curve. The quantity adjustment in stratum m, due to income changes in that stratum at constant prices, is given by

$$(4) \qquad \Delta d^*_{i(m)} = b_{(m)} E_{i(m)} q_i^0{}_{(m)}.$$

The price change is the same for all strata $(p_i^1 - p_i^0)$, since all strata are faced with the same market. Hence, the quantity adjustment in stratum m, caused by the change in price, is given by

$$(5) \qquad \Delta d^{**}_{i(m)} = \frac{p_i^1 - p_i^0}{p_i^0} e_{i(m)} q_{i(m)}^0,$$

and the total change in the quantity of commodity i demanded by stratum m is given by

(6)

$$\Delta q_{i(m)} = b_{(m)} E_{i(m)} q_i^0{}_{(m)} + \frac{p_i^1 - p_i^0}{p_i^0} e_{i(m)} q_{i(m)}^0$$

$$= q_i^0{}_{(m)} \left[b_{(m)} E_{i(m)} + \frac{p_i^1 - p_i^0}{p_i^0} e_{i(m)}\right];$$

where $e_{i(m)}$ is the price elasticity of demand for stratum m. If we utilize the estimates of the income elasticity of protein intake, we can then estimate the change in protein intake by stratum caused by a given change in incomes of that stratum, $\Delta Y_{(m)}$,

$$(7) \quad \Delta q_{pr(m)} = b_{(m)} e_{pr(m)} q_{pr}{}^{0}{}_{(m)} + \sum_{i=1}^{t} \frac{p_i{}^1 - p_i{}^0}{p_i{}^0} e_{i(m)} q_{i(m)} pr_i,$$

where $q_{pr(m)}{}^0$ is quantity of protein consumed by stratum m before the change, pr_i is the protein content per unit of commodity i, t is the number of commodities, and, since total supply is constant, $\sum_{m=1}^{n} \Delta pr_{(m)} = 0$.

The change in calorie intakes may be estimated in the same manner by substituting the income elasticity of protein intake and protein content per unit of commodity i for income elasticity of calorie intake and content per unit of commodity i. These equations estimate the change in protein and calorie intake by stratum for a given change in consumer incomes of one or more strata. In the case of income transfers, where total income is maintained constant, the selected changes in stratum incomes must meet the requirement that $\sum_{m=1}^{n} \Delta Y_m = 0$.

Another issue of interest here is to estimate the minimum increase in incomes of nutrient deficient strata required to eliminate the deficiency. Since all strata compete for a fixed amount of nutrients, income changes in one stratum have implications for nutrient intakes in all strata, as discussed above. Hence, reduction or elimination of deficiencies in one stratum is likely to worsen deficiencies in other deficient strata and may create deficiencies in other—previously sufficient—strata. In such cases, the minimum income increases required by each of the strata to eliminate nutrient deficiencies or to avoid the occurrence of deficiencies must be determined simultaneously.

From (7) we get

$$(8) \quad b_{(m)} = \Delta q_{pr(m)} - \sum_{i=1}^{t} \left[\frac{p_i{}^1 - p_i{}^0}{p_i{}^0} e_{i(m)} q_{i(m)} pr_i\right] \left[e_{pr(m)} q_{pr}{}^{0}{}_{(m)}\right]^{-1}.$$

The minimum income change required to meet protein requirements of a given stratum is estimated by substituting the existing protein deficiency for $\Delta q_{pr(m)}$ in (8), i.e., $\Delta q_{pr(m)} = K_{pr(m)} - q_{pr}{}^{0}{}_{(m)}$, where $K_{pr(m)}$ is the minimum protein requirement by stratum m. The minimum income changes required to remove protein deficiencies in all deficient strata and to avoid other stratas becoming deficient are estimated by solving simultaneously equation (8) for each of the strata currently deficient in protein or expected to become deficient because of income changes in deficient strata. In the case of income transfer, with a constant total income, the required transfer of income from one or more nondeficient strata is estimated as part of the above set of simultaneous equations by adding the equation,

$$\sum_{m=1}^{n} \Delta Y_{(m)} = 0.$$

Income changes required to meet calorie requirements are estimated in a similar manner.

Data Sources and Sample Characteristics

Data on quantities consumed and prices paid for each of twenty-two foods or groups of food, as well as family incomes, size, and age distribution were collected from a sample of 230 families selected from the population of Cali, Colombia, using a stratified random sampling procedure. Each family was visited twice with a time interval of about sixteen months.

The sample size for each stratum was proportional to the population among strata. The total population for the city of Cali was 923,000 according to the 1973 national census, of which 0.16% was included in the sample. The average per capita annual income was estimated by this study to be $225. Selected sample characteristics were shown previously (Pinstrup-Andersen, de Londoño, Hoover).

Empirical Results

As would be expected from casual observation, the income distribution is heavily skewed (table 1). Thus, the poorest 18% of the sample population (stratum I) obtained only 5% of total income, while the 13% with the

Table 1. Estimated Cumulative Distribution of Population, Incomes, and Calorie and Protein Intake, in Percentages

	Income Strata				
Cumulative Distributions	I	II	III	IV	V
Population	18.3	36.1	72.9	86.5	100.0
Incomes	4.9	13.6	39.1	57.7	100.0
Calorie intakes	13.6	28.4	64.6	79.7	100.0
Protein intakes	11.8	25.1	59.4	75.3	100.0

highest incomes (stratum V) obtained 42% of total incomes. The distribution of total calorie and protein consumption was also found to be skewed in favor of higher incomes, the calorie consumption distribution being slightly less skewed than that of protein. The gini coefficient for income was estimated to be 0.42, while similar coefficients for protein and calorie intake were estimated at 0.18 and 0.12, respectively.

The average daily per capita intake of calories and protein for the sample as a whole was estimated to be 112% of requirements (table 2). Hence, no additional food would be needed to fulfill calorie and protein requirements if available food were distributed according to needs. However because of the skewed distribution of available food, two of the five strata were deficient in protein, and one was deficient in calories. Actually two strata were deficient in calories. However, stratum II was within one percentage point of requirements and was, for the purpose of this analysis, not considered deficient. Assuming that changes in nutrient intakes influence nutrition only if a nutrient deficiency exists (either before or after the change), increased or decreased protein and calorie intake influences nutrition if it occurs in strata I and II, and stratum I for protein and calories, respectively. Changes in protein and calorie intakes in other strata will influence nutrition only if changes result in deficiencies.

Income and Price Elasticities

The income elasticity for each of the twenty-two foods was estimated for each of the five income strata on the basis of cross-sectional data within each stratum (table 3). The consumers within each stratum were faced with essentially the same price for any given food commodity. Furthermore, little variation in tastes and preferences was expected among consumers within a given stratum. Hence, the income elasticities were estimated simply by regressing per capita quantity consumed on per capita real income within each stratum. The estimated income elasticities were consistent with expectations. Foods of animal origin ("luxury goods") tended to have higher income elasticities than staple foods. All the foods show a decreasing income elasticity for increasing incomes, becoming negative for certain staples in high income stratum.

The income elasticity of calorie and protein intake was estimated for each income stratum (table 4). As shown in the previous section of

Table 2. Estimated Calorie and Protein Intakes and Deficit or Excess by Strata

	Strata					
	I	II	III	IV	V	Average
Estimated daily intake of calories per capita	1,904	2,119	2,510	2,831	3,836	2,552
Intake in percentage of requirements[a]	89	99	117	132	178	119
Estimated daily intake of protein per capita (grams)	44.6	51.6	64.6	81.1	126.4	69.2
Intake in percentage of requirements[a]	72	83	104	131	204	112

[a] Based on estimated requirements for Colombia (Williamson, Mora Parra, Pardo-Tellez).

Table 3. Income Elasticities by Strata

	Strata					
Commodity	I	II	III	IV	V	Average
Beef	1.52	1.35	0.99	0.67	0.47	0.84
Pork	1.94	1.65	1.12	0.82	0.69	1.02
Eggs	1.37	1.24	1.27	0.75	0.35	0.93
Milk	1.83	1.65	1.13	0.63	0.20	0.77
Rice	0.42	0.39	0.39	0.26	0.19	0.34
Maize	0.63	0.54	0.44	−0.26	−0.43	0.39
Beans	0.80	0.77	0.64	0.45	0.25	0.60
Lentils	0.90	0.90	0.73	0.62	0.43	0.64
Peas	1.13	1.13	0.75	0.58	0.51	0.70
Other grains	0.86	0.49	0.38	0.29	0.25	0.47
Potatoes	0.40	0.41	0.31	−0.30	−0.31	0.16
Cassava	0.22	0.27	0.24	−0.41	−0.44	0.12
Vegetables	1.12	0.99	0.87	0.37	0.20	0.68
Tomatoes	1.18	1.26	1.00	0.46	0.28	0.83
Plantain	0.52	0.48	0.39	−0.31	−0.29	0.32
Oranges	1.14	0.96	0.78	0.64	0.29	0.69
Other fruits	1.31	1.21	0.84	0.66	0.49	0.75
Bread and pastry	0.65	0.55	0.32	0.24	−0.15	0.27
Butter and margarine	2.85	2.26	1.52	0.69	0.39	1.09
Sugar	0.31	0.29	0.29	0.20	0.09	0.24
Oils and fats	0.83	0.81	0.57	0.30	0.14	0.50
Processed foods	1.89	1.44	1.31	0.66	0.42	0.91
Nonfood	1.12	1.02	1.33	1.47	1.34	1.57

this paper, these elasticity estimates are obtained from the income elasticities of demand for the various commodities weighted by the calorie and protein content, respectively. Hence, as is the case for most income elasticities of demand, the income elasticity of calorie and protein intake is less than one and inversely correlated with income level. The income elasticity of calorie intake is smaller than the income elasticity of protein intake for all strata. The principal reason for this is that high protein foods tend to have higher income elasticity of demand than low protein foods.

Price elasticities of demand were also estimated for each food and income stratum. These estimates were reported previously (Pinstrup-Andersen, de Londoño, Hoover). No attempts were made to estimate price elasticities of supply. Rather, as earlier mentioned, the analyses to follow were carried out under two alternative assumptions regarding the supply.

Nutritional Impact of Changes in Incomes and Their Distribution

The estimated impact of changes in consumer income distribution on calorie and protein intakes is presented in this section. Three means of changing existing income distribution are considered: (*a*) increasing the incomes of calorie- and protein-deficient strata, maintaining the incomes of other strata constant; (*b*) redistributing current incomes from the highest income stratum to the calorie- and protein-deficient strata, maintaining total incomes constant; and (*c*) reducing the incomes of the highest income stratum, maintaining other incomes constant. The nutritional impact of each of these three means is compared with those of increasing incomes of all strata, maintaining current income distribution. In order to compare the results, an arbitrarily selected 1% of total incomes is used as the amount available for distribution in all cases.

Table 4. Income Elasticity of Calorie and Protein Intake by Income Strata

	Strata					
Commodity	I	II	III	IV	V	Average
Calories	0.69	0.69	0.60	0.35	0.23	0.51
Protein	0.92	0.90	0.73	0.50	0.35	0.65

Since the relationships considered here are linear, the impact of changes in the income distribution of magnitudes different from 1% of total incomes may be estimated by simple extrapolation. One percent of total incomes is equal to 20.6% of incomes of stratum I, 11.8% of those of stratum II, 3.9% of those in stratum III, or 5.4% and 2.4% of the incomes of strata IV and V, respectively. As mentioned earlier, the estimates are made for two alternative assumptions: a perfectly inelastic supply or a fixed quantity of food irrespective of price, and a perfectly elastic supply or a capacity to shift the supply curve to meet increases in demand at constant prices. The supply expansions required to maintain constant prices under the latter assumption are estimated for each of the twenty-two commodities. The nutritional impact of changes in the income distribution without supply increases is discussed first.

Income Redistribution Under Fixed Food Supply

Table 5 shows the estimated change in per capita calorie and protein intake caused by alternative changes in consumer incomes and their distribution. Five means for changing the income distribution are considered. These are: (*a*) increasing the incomes of stratum I, maintaining incomes of all other strata constant; (*b*) increasing the incomes of stratum II, maintaining incomes of all other strata constant; (*c*) increasing the incomes of strata I and II simultaneously by equal amounts; (*d*) transferring incomes from stratum V to strata I and II, respectively; and (*e*) decreasing incomes of stratum V, maintaining all other incomes constant. In addition, the impact of increasing all consumer incomes by a uniform 1%, and, thus, maintaining current income distribution, is estimated for comparison purposes. In all cases the amount of income change is the same and equal to 1% of total incomes.

An increase in all consumer incomes without changing the income distribution in a situation of fixed food supplies results in a transfer of calories and protein from higher to lower income strata and, hence, has a positive nutritional impact. However, the magnitudes of such transfers are small and, even for large increases in consumer incomes, the impact on nutrition will be very limited (table 5). If, instead of being distributed proportionally among all strata, the same amount of income

Table 5. Estimated Impact of Alternative Changes in Incomes and Their Distribution on Calorie and Protein Intake under a Fixed Supply

Stratum for Which Income Is Increased	Stratum for Which Income Is Decreased	Change in Per Capita Calorie Intake (cal/day)					Change in Per Capita Protein Intake (gr/day)				
		I	II	III	IV	V	I	II	III	IV	V
All (1%)	none	0.60	0.71	0.46	−1.22	−1.77	0.014	0.016	0.007	−0.023	−0.035
I (20.6%)	none	205.66	−53.00	−55.89	−34.54	−30.77	6.492	−1.513	−1.567	−1.269	−1.341
II (11.8%)	none	−29.21	135.01	−34.63	−22.29	−21.53	−0.833	4.368	−1.029	−0.899	−0.966
I (10.3%) & II (5.9%)	none	88.08	41.07	−44.10	−28.77	−25.92	2.831	1.428	−1.300	−1.071	−1.143
I (20.6%)	V (2.4%)	207.35	−51.08	−49.56	−34.69	−47.19	7.111	−1.393	−1.358	−1.269	−2.150
II (11.8%)	V (2.4%)	−28.16	138.94	−31.73	−19.80	−37.94	−0.751	4.525	−0.894	−0.727	−1.783
None	V (2.4%)	2.11	2.72	3.20	3.44	−20.70	0.107	0.126	0.131	0.135	−0.897

were totally received by nutrient-deficient strata, the reduction in calorie and protein deficiencies could be considerable. If the nutrient-deficient strata receive the additional incomes as a result of income transfers from the high income strata rather than a net increase to total incomes, the nutritional impact will be larger. A reduction in the incomes of high income consumers has a positive impact on calorie and protein intakes among lower income groups. Thus, a reduction of the incomes of stratum V, equal to 1% of total incomes (2.4% of the incomes of stratum V), would increase per capita calorie and protein intakes in stratum I by 2.11 calories per day and 0.107 gram of protein per day, respectively. These increases are small when compared to those obtained from increasing incomes of stratum I. However, they are much larger than those obtained from a proportional increase of the incomes of all strata. Thus, since all income changes considered here are of the same dollar amount (1% of total incomes), a one dollar reduction in the incomes of stratum V would increase protein intakes in stratum I by more than seven times the increase resulting from a one dollar increase in consumer incomes when the income distribution is maintained constant.

If all other incomes were constant, an increase in the incomes of stratum I of 24.6% (1.19% of total incomes) would eliminate calorie deficiencies in that stratum (table 6). If the income were to be transferred from stratum V, the required increase would be slightly less. However, since food supplies are fixed, the transfer of food to stratum I from other strata results in calorie deficiencies in stratum II. Hence, in order to eliminate all calorie deficiencies, the income of strata I and II must be increased by 27.5% and 7.1%, respectively. This is equal to 2% of total income.

Much larger changes in income distribution are required to eliminate protein deficiencies for each of the deficient strata and for the population as a whole (table 7). Protein deficiencies in stratum I could be eliminated by increasing its incomes by 60% or by transferring an amount of income equal to 50% of current stratum I incomes from the highest income stratum. Such income increases in stratum I would increase protein deficiencies in stratum II and deficiencies would develop in stratum III. Protein deficiencies could be eliminated simultaneously in the two strata currently deficient by increasing incomes of

Table 6. Initial Calorie Intakes, Change, and Degree of Sufficiency by Stratum for Changes in Income Distribution Leading to the Elimination of Calorie Deficiencies

Stratum for Which Income Is Increased	Percentage of Increase	Stratum for Which Income Is Decreased	Percentage of Increase		Initial Calorie Intake, Change, and Degree of Resulting Sufficiency				
					I	II	III	IV	V
Initial intake	—	—	—	cal/day/cap	1,904	2,120	2,510	2,831	3,836
				level of sufficiency	89	99	117	132	178
I	24.6	none	—	cal/day/cap	+246	−63	−66	−40	−36
				level of sufficiency	100	96	114	130	177
I	24.0	V	2.8	cal/day/cap	+246	−61	−59	−41	−56
				level of sufficiency	100	96	114	130	176
I & II	27.5; 7.1	none	—	cal/day/cap	+246	+30	−95	−60	−54
				level of sufficiency	100	100	112	129	176

Table 7. Initial Protein Intake, Change, and Degree of Sufficiency by Stratum for Changes in Income Distribution Leading to the Elimination of Protein Deficiencies

Stratum for Which Income Is Increased	Percentage of Increase	Stratum for Which Income Is Decreased	Percentage of Decrease		Initial Protein Intake, Change, and Resulting Degree of Sufficiency: I	II	III	IV	V
Initial intake	—	—	—	Grams/day/cap	44.6	51.6	64.6	81.2	126.4
				level of sufficiency	72	83	104	131	201
I	60.0	none	—	Grams/day/cap	+17.4	−4.2	−4.2	−3.4	−3.6
				level of sufficiency	100	76	97	125	198
II	29.6	none	—	Grams/day/cap	−2.1	+10.4	−2.7	−2.1	−2.4
				level of sufficiency	69	100	100	127	200
I	50.5	V	5.8	Grams/day/cap	+17.4	−3.4	−3.4	−3.4	−5.4
				level of sufficiency	100	78	99	126	195
II	27.0	V	5.4	Grams/day/cap	−1.7	+10.4	−2.0	−1.7	−4.1
				level of sufficiency	70	100	101	128	197
I & II	73.3; 42.9	none	—	Grams/day/cap	+17.4	+10.4	−8.5	−6.8	−7.4
				level of sufficiency	100	100	90	120	192
I, II, & III	76.0; 50.1; 29.0	none	—	Grams/day/cap	+17.4	+10.4	−2.6	−14.2	−15.9
				level of sufficiency	100	100	100	108	178
I, II, & III	65.4; 42.0; 16.5	V	26.0	Grams/day/cap	+17.4	+10.4	−2.6	−9.1	−21.0
				level of sufficiency	100	100	100	116	170

strata I and II by 73% and 43% of current incomes, respectively. Such income changes, however, would introduce severe protein deficiencies among the consumers in stratum III. Hence, to eliminate all protein deficiencies, incomes of stratum III must be increased. (This conclusion refers only to stratum averages. Protein deficiencies may still exist within a stratum.) All protein deficiencies would be eliminated if the incomes of strata I, II, and III were increased by 76%, 50%, and 29%, respectively, and all other incomes maintained constant. This is equal to an increase of 15.4% in total income. If, on the other hand, the elimination of the protein deficiencies is to come about through income transfers from the highest income group, the required income increases for the three strata would be 65%, 42%, and 17%. The total income transfer would equal 26% of current incomes of stratum V and 10.8% of total income. However, even with a reduction of 26% of current incomes, the protein intake in stratum V would be 170% of requirements, down from the current 201%. The monetary incomes of consumers in stratum IV are not affected by the above changes in income distribution. However, due to price increases, their real incomes are reduced and food consumption is reduced correspondingly. Thus, protein consumption drops from 131% to 108% of requirements if all protein deficiencies are eliminated through additional incomes for strata I, II, and IV, and to 116% of requirements if the protein deficiencies are eliminated through income transfers from stratum V.

Income Redistribution with Food Supply Expansion

This part of the analysis estimates the nutritional implications of changes in the income distribution under the assumption that food supplies are expanded to meet the increases in demands caused by these changes at constant prices. Table 8 shows the changes in per capita calorie and protein intakes caused by an increase in total consumer incomes of 1% distributed proportionally among income strata to keep the income distribution constant and received exclusively by the calorie- and protein-deficient strata, and a transfer of an amount equivalent to 1% of total consumer incomes from the highest income stratum (V) to the calorie- and protein-deficient income strata.

As would be expected, the nutritional implications are greatly influenced by the distribution of additional incomes. Thus, the calorie-deficient stratum increases the per capita calorie consumption by 13 calories per day if current income distribution is maintained and by 272 calories per day if the total income increase is received by that stratum. Similar differences are found for protein. Since sufficient quantities of food are assumed to be available to meet demand expansions at the current price, an increase in the incomes of strata I or II will have the same nutritional impact, irrespective of whether the incomes are transferred from other strata or whether they are increases to current total incomes, unless the transfer results in deficiencies in

Table 8. Estimated Changes in Calorie and Protein Intakes Caused by Changes in Consumer Income Distribution under Constant Food Prices

Change in Per Capita Calorie Intake (cal/day) Due to:	I	II	III	IV	V
One percent increase in incomes for all strata	13.20	14.70	15.00	9.90	8.90
Total income increase received by I	271.90	0	0	0	0
Total income increase transferred from V to I	271.90	0	0	0	−21.40
Change in Per Capita Protein Intake (grams/day) Due to:					
One percent increase in incomes for all strata	0.41	0.47	0.47	0.41	0.44
Total income increase received by I	8.43	0	0	0	0
Total income increase received by II	0	5.50	0	0	0
Total income increase transferred from V to I	8.43	0	0	0	−1.05
Total income increase transferred from V to II	0	5.50	0	0	−1.05

other strata. The impact on total demand, however, will depend on whether an income transfer is involved or not. This is discussed in a subsequent section.

The minimum increases in incomes of stratum I to meet calorie and protein requirements were estimated to be 18.6% and 42.5% of current strata incomes, respectively. These increases are equivalent to 0.9% and 2.1% of total incomes, respectively. An increase of 22.3% in the incomes of stratum II (1.9% of total incomes) is necessary to meet protein requirements in that stratum.

Impact of Changes in Income Distribution on Demand

The increase in demand of each of the commodities caused by the previously mentioned changes in incomes and income distribution is estimated in this section. The estimates represent the required increase in supplies to maintain prices constant under free market conditions. The shift in the demand curve caused by a uniform 1% increase in all consumer incomes is given by the average income elasticities. If, instead of a uniform percentage increase in all consumer incomes, the total income increase was received by nutrient-deficient strata, the increase in demand for all commodities would be considerably larger (table 9). Thus, the increase in the demand for basic staples such as cassava, potatoes, rice, and maize would be from four to twenty-eight times higher if the total income increase was received by stratum I instead of a uniform percentage distribution of the additional income across strata. As an example, the demand for cassava would increase by about 0.1% if all incomes were increased by 1%. However, if an equal amount of income was received totally by the lowest income group, the demand for cassava would increase by more than 1%. However, the impact of income distribution on food demand is not limited to basic staples. Thus, the demand for beef would increase by 0.8% if all incomes were increased by 1%, and 2.2% if the same total income was received by stratum I. Income transfer from higher to lower income consumers may also have great impact on food demands. Thus, the transfer of an amount of income equal to 1% of total population incomes from the highest to the lowest income stratum, maintaining total population incomes constant, would increase the demand for beef, pork, and eggs by about 2%; vegetables, maize, and beans by about 2.5%; and plantain and certain grains by more than 3.5%. This clearly points out the need for including changes in income distribution in demand forecasting if any such changes are expected.

Policy Implications

According to the findings of this study, considerable improvements in human nutrition can be made, even in the absence of expansions in overall food supply, by allowing a larger proportion of income growth to be obtained by nutritionally deficient income groups. This, of course, would be true only if the nutrient intakes of a portion of the population are significantly above minimum requirements. Likewise, even at a fixed total food supply and a fixed total consumer income, transfer of income from nondeficient to deficient groups offers great potentials for improving human nutrition. Distribution-neutral income growth offers little scope for reducing caloric and protein deficits in the deficit strata if the total food supply is fixed. Although a small transfer of calories and proteins has been observed in the presented analysis, these small improvements may be reversed if account is taken of price cross-elasticities of demand. If the food supply can be expanded to maintain food prices constant, increases in consumer incomes may result in considerable improvements in human nutrition, even in the absence of changes in relative income distribution. However, such an approach entails considerable nutritional waste because a large part of the additional food is consumed by nondeficient consumer groups.

Similarly, policies aimed at the expansion of food supplies without a simultaneous increase in the incomes of nutrient-deficient consumer groups entail large nutritional waste and, for that reason, are relatively ineffective (Pinstrup-Andersen, de Londoño, Hoover). The most effective approach appears to be simultaneous increases in the purchasing power of deficient groups and in food supply. However, if supply-expanding activities are costly and income redistribution is feasible, the most efficient policy approach to eliminating malnutrition might be either income transfers from higher to lower income groups through income or property taxes and similar measures or increasing incomes only, or

Table 9. Estimated Increase in the Demand for Each of Twenty-Two Food Commodities under Alternative Changes in Consumer Incomes and Their Distribution

Commodity	Current Con-sumption	Estimated Demand Increase: Unchanged Distr.		All to I		All to II		Transfer V to I		Transfer V to II	
	(tons/day)	(kg/day)	(% incr.)	(kg/day)	(% incr.)	(kg/day)	(% incr.)	(kg/day)	(% incr.)	(kg/day)	(% incr.)
Beef	87.5	733	0.8	1,968	2.2	1,486	1.7	1,620	1.9	1,137	1.3
Pork	27.3	278	1.0	662	2.4	610	2.2	506	1.9	455	1.7
Eggs	25.1	232	0.9	616	2.5	539	2.1	562	2.2	486	1.9
Milk	144.9	1,121	0.8	2,874	2.0	2,231	1.5	2,631	1.8	1,989	1.4
Rice	83.9	289	0.3	1,201	1.4	680	0.8	1,152	1.4	631	0.8
Maize	72.0	284	0.4	1,833	2.5	1,000	1.4	1,880	2.6	1,048	1.5
Beans	22.8	137	0.6	540	2.4	367	1.6	518	2.3	344	1.5
Lentils	9.4	60	0.6	99	1.1	99	1.1	69	0.7	69	0.7
Peas	12.1	84	0.7	142	1.2	141	1.2	93	0.8	93	0.8
Other grains	40.8	193	0.5	1,870	4.6	149	0.4	1,828	4.5	106	0.3
Potatoes	73.0	117	0.2	1,051	1.4	682	0.9	1,139	1.6	770	1.1
Cassava	65.7	27	0.1	758	1.1	462	0.7	816	1.2	521	0.8
Vegetables	92.8	634	0.7	2,618	2.8	1,554	1.7	2,528	2.7	1,464	1.6
Tomatoes	38.6	319	0.8	1,420	3.7	736	1.9	1,372	3.6	688	1.8
Plantain	100.3	321	0.3	1,988	2.0	1,289	1.3	1,936	1.9	1,236	1.2
Oranges	191.8	1,325	0.7	3,467	1.8	2,653	1.4	3,163	1.6	2,349	1.2
Other fruits	74.4	555	0.7	1,252	1.7	1,181	1.6	932	1.3	861	1.2
Bread and pastry	24.7	67	0.3	398	1.6	226	0.9	419	1.7	247	1.0
Butter and margarine	13.8	150	1.1	332	2.4	286	2.1	292	2.1	245	1.8
Sugar	72.3	174	0.2	719	1.0	357	0.5	689	1.0	327	0.5
Cooking oils and fats	23.3	111	0.5	424	1.8	306	1.3	409	1.8	290	1.2
Processed food	32.1	291	0.9	543	1.7	610	1.9	423	1.3	120	0.4

primarily, among low income groups through productive public works programs or similar activities, with little or no emphasis on food supply-expanding policies.

Since the income elasticity for food usually is less than one, only a part of the income transfers from higher to lower income groups would be spent on food. Hence, in addition to reducing or eliminating malnutrition, such transfers would influence the relative purchasing power for other goods.

Changes in the distribution of consumer incomes is likely to have considerable impact on the demand for individual food commodities. Therefore, any attempts to expand simultaneously food supply and purchasing power of low income consumers should take into consideration the price and income elasticities for these low income consumers. The utilization of average estimates of price and income elasticities for the population as a whole for the projection of individual commodity demand is not likely to be very successful if significant changes occur in the income distribution.

Income distribution and food supply policies have been discussed exclusively from the point of view of one potential goal: improving human nutrition. But these policies, if implemented, will have implications reaching far beyond human nutrition. Some will influence the extent to which other goals are achieved; others will influence factors which, in turn, may have an impact on human nutrition. Such indirect impact may oppose and even offset the direct impact. Hence, while this analysis has focused on the direct nutritional impact of changes in the distribution of consumer incomes, the resulting changes in food demand, and the needs for food supply-expanding policies, the findings are primarily useful for guiding public policy if they are considered within the overall economic planning and policy formulation. Single-minded policies aimed at the elimination of malnutrition in the short run without due consideration to other implications of such policies, may result in a worsening of the nutritional situation in the long run and may ignore other equally or more important goals.

Limitations and Needs for Further Research

A number of limitations regarding the methodological approach and the empirical findings should be mentioned. First, the validity of elasticity estimates—whether it is price or income elasticities—may be questionable for large changes in prices, incomes, or quantities consumed. However, while the exact value of these estimates may be valid only for small changes, the authors believe that the relative magnitudes and direction of the elasticities are valid for the changes considered in this paper. Another limitation refers to the procedures used to estimate price elasticities. This is discussed in an earlier article (Pinstrup-Andersen, de Londoño, Hoover) and will not be repeated here.

The analysis presented in this paper does not consider intrafamily distribution of nutrients. Thus, while the nutrient requirements for the family as a whole may be met, deficiencies may still exist among certain members of the family, e.g., small children and pregnant women. Hence, the analysis deals with the potential reduction or elimination of nutrient deficiencies by increasing food consumption by the family as a whole. Nutrition education may be required to assure optimal distribution of nutrients within the family. Additional research is needed to relate changes in food supply and consumer incomes to changes in nutrient intakes by the most vulnerable members of the family.

The empirical analysis is limited to protein and calories. However, the methodological approach allows the incorporation of other nutrients, such as vitamins. Furthermore, protein intake may be presented as essential and nonessential amino acids.

The methodology, as presented in this paper, is valid only for consumers who do not produce the particular food commodities. Furthermore, the analysis takes no account of nutritional implications of the multiplier effects of changes in food supply and consumer incomes and a possible interaction between income source and nutritional intake. Because a considerable proportion of calorie and protein deficiencies are found among low income farm families, research is needed to improve our knowledge of the nutritional implications of public policies aimed at increasing the incomes of low income farmers and expanding food supplies. The concept of marketable surplus, household economics concepts, and the methodology presented in this paper may offer a point of departure for such research. Regarding the influence of income source, additional work is needed for landless farm workers to improve our understanding of the

relationships among food supply expansions, wage earnings in the farm sector, and nutritional implications.

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An Analytical Framework for Extension Community Development Programming in Local Government

George R. McDowell

Current Extension programming in community development, much of it directed at local government problems, appears a potpourri of stylistic approaches. The public choice paradigm explicitly establishes a theoretical basis for the view that government's primary role is providing for resolution of the constant and inevitable conflicts between the values of citizens. It views the level and mix of services provided by government as a reflection of that political process rather than a scientifically determinable optimum. These arguments clarify differences between "process" and "substantive" approaches to Community Resource Development programming and suggest a framework for Extension strategies for improving local government.

Key words: citizen effectiveness, Extension strategies, government system capacity, public choice.

The initiation of Community Resource Development (CRD) programs within Cooperative Extension Service programming in the mid-1950s may be viewed as a realization that existing programs failed to serve some of the educational needs of Extension clientele. For the most part, the existing programs provided functional education for a wide range of individual decisions. There remain, however, a large number of problems affecting individuals that require a collective decision. The Extension Community Resource Development program was and is directed toward such problems. The 1976 Report of the Extension Committee on Organization and Policy's (ECOP) Subcommittee on Community Resource Development and Public Affairs is a contemporary statement to this effect.

Current Extension programming in community development is a potpourri of stylistic approaches. There are strong advocates for so called process approaches which focus on procedural techniques and issues and the processes involved in group decision making as the basis for evaluating whether community development is taking place. The argument for this approach is that since it is not possible to determine the "best" alternative on the basis of outcome in many collective decision situations, the only evaluative approach that can be used is one that determines whether the process and procedures used in arriving at a decision were appropriate. If the process of decision making followed is systematic, just, and correct, then the decisions must be appropriate and correct.

There are others who characterize their approaches to community development as "substantive." This use of "substantive" is usually meant to be in contrast to, and an implied critique, of the process approach to community development. Advocates of this position argue that many community decisions can be evaluated on the basis of outcomes, using the analytics of the natural, engineering, or management sciences; these analytical sources become the basis of their "substance."

Each of these approaches to community development generates useful programs. However, none of them provides an overall framework which explicitly considers the function, organization, and performance of local government. Since local jurisdictions of government, whether single or multipurpose, are the ultimate focus of much of the collective decision making to which much of Extension

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Community Resource Development programming is directed, and since local government is frequently the direct locus of CRD activities, the inclusion of a perspective on local government within an analytical framework will be useful for program development and evaluation.

Literature about the organization of local government coming out of the "public choice" school of thought in economics, public administration, and political science and the debate surrounding that view provide some of the necessary framework. The following discussion will elaborate the public choice view of local government and its organization, the counter view of the "consolidation reform tradition," and will suggest how CRD Extension efforts fit the overall framework of analysis. In addition some long-term strategies for CRD programming in local government will be suggested.

The Function and Organization of Local Government

In describing the dimensions of government, Dahl and Tufte discuss the functioning of government in terms of government system capacity and citizen effectiveness. The notion of system capacity means essentially the degree to which government effectively provides for the agreed-upon mix and level of services. Citizen effectiveness is the effect of government organization and process on the articulation of citizen preferences.

Dividing the function of government into these two distinct aspects alludes to a perception that the products of government system capacity are a reflection of the collective values and preferences of citizens. The sorting out of conflicting values and preferences necessary to arrive at some degree of agreement is the grist of local political processes and in terms of the individual is described as citizen effectiveness.

The organization of local government has provoked continuous and vigorous debate. The prevailing view on the issue within public administration and political science circles since the 1920s is the so-called "consolidation reform tradition" (Bish and Ostrom). The consolidation-reform view is included in this discussion because, although the metropolitanization-through-consolidation movement has lost the fervor of a decade ago, it still represents the intellectual paradigm which dominates the view of local government malaise, reform, and modernization (Ostrom 1973). For an example that the consolidation view is alive and well in the 1970s, the recommendations for changes in local government in Michigan by Verburg and Church in the 1973 *Proceedings of the Public Policy Forum on the Alternatives for Michigan Local Government* will suffice.

The Consolidation Reform Tradition

When considering the problems of local government, analysts in this reform tradition view small units as unprofessional and inefficient. The commitment of small jurisdictions to local interests is seen as parochial and as standing in the way of achieving the overall public interest of the larger community. Fragmented authority and multilayered overlapping jurisdictions among numerous units of local government are diagnosed as the fundamental sources of institutional failure in the governance of many areas, particularly urban areas.

From this perspective, overlapping jurisdictions as in the case of multiple, single-purpose government units imply duplication of services produced, with resulting waste and inefficiency. According to consolidation reformists, efficiency is enhanced by eliminating the many small jurisdictions and consolidating authority in one jurisdiction with general authority to govern each major urban or regional area as a whole. Such consolidations vest enlightened leaders and professional administrators with authority to coordinate all aspects of regional affairs through a single, integrated structure of government. Among the champions of the reform tradition has been the Committee for Economic Development.

Policy analysts in this tradition assume that in addition to the economies of scale gains to be made, consolidation will clearly fix political responsibility, making it possible for citizens to hold officials accountable for their actions. By contrast, the necessity of dealing with numerous overlapping jurisdictions is seen as overburdening citizens, confusing responsibility, and generally frustrating citizens in their efforts to control public policy. Further, efforts to solve regional problems are frustrated by chaotic bickering between these small, self-interested units.

It is clear in discussions of the organization of local government that analysts in the con-

solidation reform tradition focus primarily on government system capacity issues and do not much consider the citizen effectiveness dimensions of organizational alternatives.

The final conclusion of this view is that larger and fewer units of local government will capture the economies of scale and reduce the bickering or transaction costs of decision making. The elimination of overlapping special purpose units of government are seen as essential to the further reduction of transaction costs.

The Public Choice Perspective

The public choice perspective of local government is a construct based on a model of individual behavior. However, it goes beyond the traditional theory of markets and, as Buchanan makes clear, argues that individuals participate in political-government interactions as well as in market interactions. The public choice model is explicitly democratic. As with traditional economics applied to the behavior of individuals in markets, the individual operating as citizen is assumed to be motivated by the desire to maximize her or his own utility. The public choice view thus clearly recognizes that the consumers of government-provided services are also the citizens who determine the quantity and quality of the services provided. Within the context of the objectives of this paper, the jurisdictional boundaries of local units of government are seen as a major dimension of the structure of the marketplace in which citizens act to articulate their preferences.

Samuels sets forth several notions of relevance to understanding these "citizen effectiveness" dimensions of the public-choice perspective. He argues first that society—presumably also communities—operate under conditions of scarcity and that actors in society are interdependent. Thus, the conduct or choices of one group of individuals has an impact on others. In the process of choosing, individuals do not choose from among all alternatives but rather from among only those realistic or available alternatives—the opportunity set.

Samuels points out that traditional economic theory and welfare economics have concentrated on the choice of individuals from among the alternatives of their respective opportunity sets where each alternative has its opportunity cost. The individual's welfare is attained by maximizing within the constraints of the opportunity set. In a process of public choice, this traditional analysis is inadequate because it says nothing about the structure of the opportunity sets which in fact comprise the decision-making process.

In developing his notion of interactional choice, Samuels argues that the way in which one individual's choice affects the choices of others is by changing the structure or array of the opportunity set of those other persons. This impact of the behavior and choices of others on the structure of one's opportunity set is coercion—a neutral term in Samuels' usage. Thus, society is a system of mutual coercion in which the choices of each individual have an impact on the opportunity sets of others and, therefore, on the range of possible choices available to them.

Finally, Samuels defines power as "the means or capacity with which to exercise choice, with which therefore to coerce" (p. 65). The reciprocal of power is the exposure to the coercive capacity or power of others. By "means or capacity," Samuels means "the *de jure* or *de facto* bases by, with, or on which one acts as a chooser" (p. 65). This could include a person's property, position in an organization, accumulated human capital, or skill at negotiation, among others.

A citizen's effectiveness at articulating preferences is seen as a process of interactional choice where, when one person's or group's preferences count, those of another will not count. The effect of community boundaries on size (number of voters) and composition of a community can clearly affect the structure of citizens' opportunity sets and their effectiveness in public choices. Efforts at improving the performance of local government should not ignore this dimension of government or the potential for enhancing its performance through improved citizen participation.

In examining the government system capacity issues, the public choice advocates draw on conventional economic notions. They distinguish between the production and consumption of goods and services. They focus on the characteristics of goods and acknowledge that production characteristics are technology specific. Thus the "publicness" or the scale of production technology of a good or service will help instruct the way in which its provision is organized. The following section comparing the consolidation and public choice

perspectives will elaborate on these and other system capacity dimensions from the public choice view.

Comparisons of Consolidation and Public Choice Perspectives

On examining the arguments of the consolidation reform tradition on local government organization, the public choice view first argues that, since economics to size are commodity and technology specific, the simultaneous optimality in size of all services for any size local unit of government is difficult to imagine. Similarly, the public choice perspective acknowledges the possibility of diseconomies to size. Writers such as Bish and Warren argue that diseconomies of size are most likely to occur where production of the service or commodity is largely dependent on personal interactions, as is the case in schooling or counseling services. Ostrom and Parks cite research findings which indicate that citizens are more satisfied with police services in smaller jurisdictions than are citizens of comparable residential communities within larger jurisdictions of government. This work by Ostrom and Parks, and other efforts of Elinor Ostrom, raise serious questions about the measurement of output (and implicitly of economies to size) of publicly provided services by suggesting that the final measurement must be in terms of "consumer-citizen satisfaction."

In arguing on behalf of reform through consolidation, the presumption is made that if consumption of the good is to occur, the consuming unit of government must itself produce the service. The rejection of this presumption in the public choice analysis permits consideration of a host of alternative arrangements between units of local government. Intergovernmental production arrangements such as contracting, mutual aid agreements, and joint ventures make it possible to capture production economies to size without necessarily increasing the size of the consuming decision-making unit.

This separation of consumption and production activities also suggests another error in the logic of the consolidation reform argument. Since, according to that argument, the objective of consolidation is greater efficiency in production (i.e., system capacity), it assumes that the goals within which that efficiency is defined are known and constant. However, in the case of publicly provided services where the goals of production are defined by the preferences of consumer-citizens, a change in the consuming unit or group will likely change the production goals. The satisfaction of consumer-citizens would seem to be more readily achieved under multiple smaller consuming units, each with its own level and mix of services, than under a single large consuming unit with a single level and mix of services.

The consolidation reform objective of reducing the bickering and haggling of transactions costs between units is based on the presumption that these costs will be lower when multiple jurisdictions are subsumed under a single authority. This assumption also has supported the basic opposition to the growing numbers of special purpose districts with their overlapping boundaries. However, in the absence of total authority and power vested in a single individual, there still will be transactions costs within consolidated or regional governmental units. Anyone who has worked in a large organization knows that a great deal of bickering and squabbling takes place over decisions within such an organization. Whether such costs will be higher or lower under governmental consolidation is difficult to predict beforehand. It is likely that negotiations or transactions within a single large governmental unit will be less visible to public scrutiny than would be the case in transactions between several smaller units. In a democratic society, this may be considered a less desirable attribute.

The consolidation reform view virtually ignores the citizen effectiveness dimensions of government and so this comparison of the two views has focused principally on those aspects of governmental organization which relate to its system capacity. While a full discussion is beyond the scope of this paper, it is appropriate to note that the implied desirability of enhancing the effectiveness of citizens and encouraging their participation, which is manifest in this paper, is not universally accepted by political theorists. In fact, as Pateman points out, most recent democratic theorists reject the efficacy of wide citizen participation in government and one must return with some exceptions to Rousseau and John Stuart Mill for a clearly participatory theory of democracy. Thus, there is also a contemporary literature for and against citizen participation, again beyond the scope of this paper. Those

who wish to start with that literature may refer to Pateman.

Strategies to Improve the Performance of Local Government

The previous section on the function of local government makes clear that the improvement of local government should include issues related to improving citizen effectiveness and government system capacity.

The consolidation reform tradition as an approach or strategy to improving the performance of local government emphasizes government system capacity. The public choice perspective finds that argument deficient, questions whether system capacity will indeed be improved as argued, and suggests that issues of citizen effectiveness be explicitly included. Finally, when citizen effectiveness considerations are included in considerations of the organization of local government, there does not appear to be *prima facie* evidence that bigger is better. Indeed, there is reason to suspect that smaller units of government may provide services in ways (levels, mix, style, and process of deciding) that are more satisfactory to their consumer-citizens. It is not the intent of this paper to argue that smaller units of government are "better" or even more beautiful. It is the intent of this paper to argue that strategies based on a presumption that bigger is better are suspect.

By discussing these issues in the context of Extension programming, this paper contends that the performance of local government can be improved by increasing or modifying the supply of information from Extension. The public choice perspective argues that information strategies should be directed to both decision makers and citizens. Other dimensions of the public choice view suggest information strategies within the broad areas of increasing government system capacity and citizen effectiveness. Some of these will be discussed in the sections that follow.

When conceptualizing an information system for local government, it is necessary to distinguish between categories of information. The discussion here identifies the following kinds of information: (*a*) institutional—the legal, administrative, or procedural rules that enable or restrict the actions of locally elected, appointed, or employed officials and citizens; (*b*) technical-analytical—that information which finds its basis in the natural, engineering, or managerial sciences; and (*c*) personal and group process skills—the range of knowledge and the skills that make an individual an effective public speaker, organizer, and leader.

Extension Strategies to Increase Local Government System Capacity

Interlocal governmental relations. The perception that production economies to size of publicly provided services exist but are technology specific and that consuming units of government need not themselves produce all of their goods or services suggests substantial research and Extension activity in enhancing the range of intergovernmental arrangements. These would include work on contracting, mutual aid agreements, and joint ventures as well as economies to size issues. The research by Sinclair on the economics of contracting for police services is an example of research in this area. Similarly, in Massachusetts an Extension CRD agent worked with several towns to assist them in jointly hiring a qualified building inspector which none of the communities could singly afford to do.

Education of locally elected, appointed, and employed public officials. Increasing the skill, insight, and acumen of decision makers is a means to increase system capacity and productivity. This approach is unique to the public choice perspective only as it influences the choice of educational content. Much of the existing CRD Extension efforts fall into this category. Indeed, many of the other strategies discussed here must be employed in tandem with this one.

The educational content of programs under this strategy is either technical or institutional in nature. The technical information involved might range from storm water management to fiscal impact analysis to shade tree care. Much of the Land Grant systems' knowledge and investments in botanical, natural resource, and engineering science and technology can be brought to bear on community problems through this strategy. Further, much of the technological information used and needed is not state or region specific and is somewhat transferable. For example, information on Dutch Elm disease from anywhere in the country will probably be useful in guiding New England towns in deciding what kinds of pub-

lic investments to make to save the elms on their town commons.

The institutional information used in educational programs under this strategy is the most limiting and costly part of making this strategy effective. By institutional information is meant the legal, administrative, or procedural rules that enable or restrict the actions of locally elected, appointed, or employed officials. While some of the pertinent institutional information is about federal rules and regulations, most is about state level regulation, and thus is virtually nontransferable across state lines.

Efforts to develop regional and national Extension materials on land use illustrate this dilemma. Such materials are useful only in broad background education. State-specific written materials are costly to produce. As a result, educational activities by Extension and other agencies tend to be one-shot meetings organized around the one or two authoritative speakers in the state. Such ad hoc meetings are great for the region of the state where they are held but hardly can be considered "Extension programming" because of the limited coverage and continuity of service of the desired audience usually provided by this means.

The major implication of the public choice perspective for this strategy is that it accepts the perception that large numbers of part-time elected and appointed officials as well as a few employed professional public administrators must be trained and educated. Such training must be an ongoing process, considering the high turnover of such officials, and this argues for Extension investments in the state-specific institutional information. Good examples of this type of material are those developed by Weeks on the duties and responsibilities of local officials in New Hampshire, and by August and Mitchell on zoning in Massachusetts.

Information systems for local officials. Local units of government must deal with an enormous quantity of information. Much of that information originates outside of the local jurisdiction, and much more, like land records or tax records, is generated within the community or by the local government itself. Extension can and does play a role in assisting local officials and local government in dealing with this information. Two dimensions of this strategy are discussed below.

Manuals and references for local officials. A major dilemma faced by local decision makers, particularly volunteer or part-time officials, is that of becoming acquainted with the plethora of detailed rules and ordinances under which they must operate. The development of cross-referenced manuals for use by persons in specific roles or positions in local government can make a major contribution to the performance of these officials.

This strategy may seem redundant after the earlier discussion of educational skills development. The distinction is a matter of detail and degree. If relevant reference materials for a particular position are developed under this strategy, it is clear that the educational effort of the previous strategy can more easily be accomplished. However, the objective of this strategy is the production of manuals and references, the usefulness of which are measured by how complete, up-to-date, and easy to use they are. Thus, the Extension/research effort is focused on the development of hard copy materials that are easily usable. The easily usable part is no mean requirement. The efforts of the Local Government Project at Cornell is a laudatory example of this strategy in action. The information included in such manuals and references is most likely to originate outside of the local jurisdiction at state or federal levels.

Data handling systems. Another appropriate and feasible CDR Extension contribution to local government is in the area of data-handling systems. On 15 March 1976 the Rural Development Service of the U.S. Department of Agriculture released for public use the Federal Assistance Programs Retrieval System. FAPRS is a computer software package and update support system which thumbs the approximately 1100 programs of the *Catalog of Federal Domestic Assistance,* the source of information on all federal assistance for which explicit requests or application must be made. Extension programs in approximately forty-five states offer the FAPRS search system to local units of government. This is an example of a data-handling system that assists local units of government and local officials to deal with data originating outside their communities in which they have considerable interest. Extension USDA support to this type of CRD effort has been most helpful and, when such information has a federal origin, ES/USDA could usefully take the initiative in developing such systems.

According to recent research by Lewis, in

1975 the records of approximately 64% of assessment jurisdictions were maintained manually without automated data-processing assistance. Wunderlich, in his study of an approach to improving at low cost the record system of Rappahannock County, Virginia, makes clear that improved data-handling systems need not be highly complicated or expensive and can be cost-effective for even small units of government. The case described by Wunderlich included only a minimum of data-processing activity for which the community required any outside assistance.

The long history and experience in Extension of information systems for farm management decisions and education appear to be highly relevant to improving the handling of internally generated data, including accounting data, for small local units of government. In addition to the direct advantages to individual jurisdictions, there would be substantial research benefits from such a program. Both research and other policy analysis, as well as local performance analysis, would be substantially enhanced by the adoption of comparable accounting methods by as many local jurisdictions as subscribed to a computerized accounting system. State regulations on local financial management, such as minimum or maximum balances in specific accounts, could easily be incorporated into accounting software packages.

Changing circumstances in communities require new and different data and analysis. Many CRD Extension personnel spend substantial amounts of time assisting individual communities in dealing with particular problems. Thus, there are innumerable community surveys conducted, impact analyses made, and physical, social, or economic measurements taken. In some settings, unique problems lend themselves to routine analyses and these are built into computer software packages, as was done in South Dakota on economic development impacts (Morse, Bateman, Tauer). Substantial efforts are made to develop simpler or more refined methodologies to conduct such problem analysis. In some degree, the continued education of locally elected, appointed, or employed officials is based on the kinds of methods, materials, and data developed by this type of CRD Extension research effort.

If community accounting systems are computer-assisted, as discussed above, a wide range of routine analyses may be incorporated just as has been accomplished in the Extension farm management area.

Extension Strategies to Increase Citizen Effectiveness in Local Government

There are any number of classification systems which could be applied to citizen effectiveness education approaches. One could be based on the degree of citizen motivation for involvement in, or conversely, on the degree of individual alienation from, the political process. Another could be based on a classification of the goods which are being provided, such as citizen involvement in natural resource issues. Yet another method could group citizens by socioeconomic class, ethnicity, or age, and deal with strategies based on one or another of these similarities or differences. The system employed here will be based partially on the audience, Extension administrative structures, and information requirements. Ultimately any classification system arrived at, in order to give insight to Extension programming, must provide the basis for distinguishing between program content and delivery mechanisms.

Youth programs. Efforts to create meaningful experiences for young people by encountering and learning about local government decision making provide at least anecdotal evidence that strongly supports this strategy for improving the present and future effectiveness of young citizens.

While there are numerous laudable examples of this approach developed throughout the country, it remains relatively difficult to obtain 4H field staff investments on behalf of this strategy.

Individual training motivation for citizen involvement. Through a kind of assertiveness training, individual training for citizen involvement seeks to instill in individuals the personal confidence required to question, challenge, or assert themselves when their preferences are not being met. In some circumstances this strategy is called "leadership development." At other times it is directed explicitly at persons who appear to be substantially disenfranchised and perhaps should be characterized as "citizenship development."

A characterization of this strategy might be that in response to a community problem, it prompts citizens to ask "who's in charge" and

provides them with personal and interpersonal skills that help them find out who indeed is in charge.

Understanding local government processes. Almost in contrast to the previous strategy, which is highly process-oriented, teaching citizens about local government processes is a strategy that seeks to describe in some detail and in understandable language who is "in charge" for a whole set of community decisions. Much of the materials developed for the training of elected and appointed local officials can be used in this method. Again, the materials developed in New Hampshire and referred to earlier are notable examples of such information. In essence, such materials describe the institutional rules, regulations, and responsibilities involved in local decision making, the rules of the game.

Understanding government performance. In the discussion above, under strategies to increase government systems capacity, data generation and analysis are included as important in improving management and decision making. Much of that same information and analysis are highly important in improving the public debate over the level and mix of services and associated expenditure by citizens.

A specific example may be helpful. Program Performance Budgeting (PPBS) or variations on the same, have been lauded, debated, and employed as an internal management tool to make more rational public financial decision making. It may be that PPBS is as important as a citizen information device and assistance to public scrutiny and debate as it is an internal management tool.

Extension efforts to help officials understand local performance data and analysis and budgeting can also be used to assist citizens in effectuating changes in the performance of local government more consistent with their preferences.

Conclusion

When the primary role of democratic government (particularly at the local level) is seen as providing for the resolution of the constant and inevitable conflict between the personal values of citizens, when the level and mix of services provided by government are seen as a reflection of the outcome of the conflict resolution of the political process rather than a scientifically determinable optimum, then strategies for the improvement of the performance of government take on somewhat new dimensions. The public choice perspective to government explicitly establishes a theoretical basis for this view of government. The division of the function of government into those relating to citizen effectiveness and those relating to government system capacity helps to identify strategies to improve the performance of government.

This division of functions of governments within the public-choice perspective resolves the seeming conflict between the process approach and the "substantive" approach to community development. The view that community development measurement or evaluation must be based on the legitimacy of the process of decision making is very close to the public choice emphasis of the political process of decision making and the effectiveness of consumer-citizens in that process. By arguing that the characteristics of goods and the technology involved in their production are important to understanding the basis of organizing their production and distribution to consumer-citizens, the public-choice perspective supports the view that the technology and analytics out of the natural, engineering, and management sciences have a role in community development. Such "substantive" information contributes not only to the government system capacity dimension of government but also assists in setting forth some of the alternatives and their consequences among which consumer-citizens must collectively choose.

The Extension strategies implied by the analysis suggest that considerable investment in state-specific information is called for in order to improve the performance of local officials and the effectiveness of citizens at the local level. The arguments of and for those strategies also suggest that there is considerable room for federal Extension leadership on federal information and on information systems for local government. Finally, the analysis suggests that a wide range of skills and knowledge are needed to help communities develop and that investments in field staff, support staff, and their placement and assignment, should reflect the diversity of community problems and the means by which they are solved.

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Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach

John L. Dillon and Pasquale L. Scandizzo

Mind experiments involving choice between risky and sure farm alternatives were used to assess risk attitudes of samples of small farm owners and sharecroppers in Brazil. Results indicate that most subsistence farmers are risk averse, and that risk aversion tends to be more common and perhaps greater among owners than sharecroppers. In an expected utility context, distribution of risk attitude coefficients (based on mean-standard deviation, mean-variance, and exponential utility functions) was diverse and not necessarily well represented by an average sample value. Econometric analysis indicated that income level and perhaps other socioeconomic variables influence risk attitude.

Key words: Brazil, expected utility, risk attitude, subsistence farmers.

Few would disagree that knowledge of subsistence farmers' choice behavior is important in terms of both micro and macro strategies for agricultural development. Doubtless for this reason, the last decade has witnessed a variety of research and speculative commentary on subsistence farmers' reactions to uncertainty. These studies might be broadly classified under the headings of (*a*) economic anthropology, e.g., Johnson; (*b*) econometrics, e.g., Moscardi and de Janvry, Scandizzo, Wolgin; (*c*) farm risk programming, e.g., Low, Sanders and Hollanda, Wiens; (*d*) sectoral risk programming, e.g., Hazell and Scandizzo, Kutcher and Scandizzo, Simmons and Pomareda; and (*e*) expected utility and safety-first theory, e.g., Benito, Masson, Roumasset. The present paper belongs to the latter category and is strongly empirical in character.

Our data comes from a sample of small farm owners and a sample of sharecroppers in northeast Brazil. To both these groups of subsistence farmers we posed two sets of simple yet reasonably realistic mind experiments involving choice between risky and sure alternatives. In the first set, the farmer's total income was uncertain but his subsistence need was assured; in the second set his subsistence requirement was also at risk. On the basis of the farmers' response we consider three topics. First, we present the sample distributions of the risk attitude coefficients α, β, and γ of the mean-standard deviation, mean-variance, and exponential utility functions, respectively, specified as

$$(1) \qquad U = E + \alpha V^{\frac{1}{2}},$$

$$(2) \qquad U = E + \beta(E^2 + V), \qquad \text{and}$$

$$(3) \qquad U = \int_{-\infty}^{\infty} (1 - e^{\gamma X})(1 - e^{\gamma})^{-1} f(X)dX$$

$$\text{if } \gamma \neq 0 \text{ and } = E \text{ otherwise,}$$

where X is a risky prospect with probability distribution $f(X)$, mean E, and variance V. Second, comparing the distributions of the estimated risk attitude coefficients for the two tenure groups and for the cases of subsistence assured and subsistence at risk, we investigate the possibility that owners and sharecroppers may react differently to risk, and that poor peasants may react differently within an expected utility context depending on whether or not there is uncertainty about the satisfaction

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of their subsistence needs. Third, using regression analysis we appraise the possible influence of some socioeconomic characteristics on the farmers' risk behavior. So far as we are aware, relative to subsistence farmers, none of these topics have previously been examined empirically in a sampling context. As a preliminary, however, we briefly outline some background to the sample and the questioning procedure adopted.

Sample Characteristics and Interview Procedure

Our data are based on two random samples respectively consisting of 66 small farm owners and of 64 sharecroppers in Canindé, a small county located in the interior of the State of Ceará in northeast Brazil. The overall group of 130 small farmers constituted a panel who were being surveyed for the third year as part of a broader research exercise on small farmers in various Brazilian regions (Patrick and Filho). Interviews in each year were largely conducted by the same group of five research assistants from the Federal University of Ceará's Department of Agricultural Economics (of which they were also graduates). Because of their local background and three-time contact, we believe these interviewers had excellent rapport with the survey panel.

The Canindé area is typical of the Sertão, the semi-arid subregion of northeast Brazil. Agriculture in these backlands is very primitive and of the slash-and-burn type with hand hoes and planting sticks. There is virtually no use of machinery, fertilizer, or improved seeds. Unemployment, malnutrition, and disease are chronic among the 15 million population; and because of extreme rainfall variability leading to both severe droughts and floods, agriculture in the Sertão is also exceedingly risky. For Canindé, the average yearly rainfall is 745 millimeters, with a 57% chance of receiving less than the average and with 67% of the rain concentrated in the four months January to April. The typical production system in the region involves tree cotton as a cash crop, corn and beans grown together for subsistence use, and beef cattle. Small owners and sharecroppers are typically involved in crop production while landlords are mainly concerned with cattle. Subsistence crop production is extremely risky from year to year and, as documented by Brooks and by Johnson, this can have calamitous implications for both small owners and sharecroppers.

Table 1 lists the means of various socioeconomic variables for the sample farmers. The data refer to the farming year 1972–73 which was average to moderately good for agricultural production and employment in the survey region. As the data show, the two samples are broadly similar in their characteristics, but the sharecroppers are on average poorer, less educated, and younger than the small owners. In absolute terms, with annual per capita mean incomes of only $153 for owners and $90 for sharecroppers, the families of both groups are extremely poor on an international basis.

The 1975 survey of the Canindé panel involved an extensive set of socioeconomic questions to which we were able to append our risk attitude questions together with a small set of questions regarding yield probabilities, ethical attitudes to gambling, and the use of omens. Dillon and Mesquita have reported on the latter questions. Both the small owners and sharecroppers were able to nominate yield probabilities as chances out of ten. Averaged

Table 1. Some Socioeconomic Characteristics of Small Farmers in Canindé, Northeast Brazil, 1972–73

Variable	Small Owners	Sharecroppers
Sample size	66	64
Proportion in region	0.20	0.80
Ave. age of family head (yrs.)	58	49
Ave. size of household (no.)	5.70	7.00
Ave. years of education of family head	0.20	0.10
Proportion of literates	0.41	0.17
Proportion of immigrants	0.45	0.61
Ave. consumption of home-grown food (Cr$)	1,233	663
Ave. net farm income of household (Cr$)	4,810	3,454
Ave. net total income of household (Cr$)	5,579	3,967

Note: In 1972–73, $1U.S. = Cr$6.4 (Brazilian Cruzeiros).
Sources: Dillon and Mesquita, Patrick and Filho, SUDENE.

for each tenure group, these implied quite similar subjective probability distributions for the yield of beans, their main subsistence crop. These distributions were typically less concentrated around the mean than a normal distribution and were positively skewed. Attitudes to gambling and the use of omens were investigated by asking the subjects a small set of questions concerning their opinions on gambling, their participation in actual gambles and lotteries, and their use of natural signs and other omens in farm decisions. Responses indicated little difference between small owners and sharecroppers. Some 30% regarded gambling as immoral; 80% had never entered a bet or lottery; and 40% specified signs (of which a third were occult) influencing their planting decisions.

The farmers' risk attitudes were appraised via their choices between hypothetical but realistic farm alternatives involving risky versus sure outcomes. These questions form the basis of our empirical analysis and were geared to finding the certainty equivalents of risky prospects involving stated probabilities. Two types of risky prospects were used, yielding two subsets of responses for each group of farmers. The first type involved only payoffs above household subsistence requirements. In these, while the level of total income was at risk, subsistence was assured. The second type of risky prospect included the possibility of not producing enough to meet subsistence requirements. Both types of risky prospect involved only two possible outcomes whose probabilities were specified as invariant frequencies. The payoff of the better outcome in the risky prospect and/or of its alternative sure prospect was progressively changed until the subject expressed indifference between the risky prospect and the sure prospect—at which point the sure prospect is the certainty equivalent of the risky prospect.

The actual questions asked followed the same basic pattern for each sample group and each risk situation. With subsistence assured, the initial question to owners was: "Which would you prefer—(A) to own a farm which gave you every year your family food requirements plus a net cash return of Cr$3500; or (B) to own a farm which in three years out of four gave you your family food requirements plus a net cash return of Cr$4200 and in one year out of four gave you your family food requirements plus a net cash return of Cr$1400?" If A was preferred to B, the cash return in A was reduced by decrements of Cr$500 until indifference or a switch to B was established. If B was preferred to A, the same procedure was repeated but with the cash return in A increased by increments of Cr$250. For sharecroppers, with subsistence assured, the initial cash sum in A was set at Cr$2000 and those in B at Cr$2400 and Cr$800, and increments of Cr$200 were used both up and down. With subsistence at risk, the initial question to owners was: "Which would you prefer—(A) to own a farm which gave you every year your family food requirements and no additional net cash return; or (B) to own a farm which in three years out of four gave you your family food requirements plus a net cash return of Cr$5000 and in one year out of four gave you just half your family food requirements and no net cash return?" If A was preferred to B, the better outcome in B was increased by increments of Cr$1000 until indifference or a switch to B was established. If B was preferred to A, the sure prospect was increased by increments of Cr$1000 until indifference or a switch to A was established. For sharecroppers, with subsistence at risk, the initial better outcome in B was set at Cr$2500. Otherwise the questions were the same as for owners with subsistence at risk.

The certainty equivalents derived from the farmers' choices are summarized in tables 2 and 3 for the subsistence assured and subsistence at risk situations, respectively. In calculating these certainty equivalents, when a switch rather than indifference was established between the sure and risky prospects, it was assumed that indifference prevailed at the midpoint of the incremental change. Regrettably, arising from lack of prior knowledge and the isolation of the survey team, the sequence of questions was terminated for some subjects before reaching certainty equivalence. These cases are shown in tables 2 and 3 as having a certainty equivalent $>$ or $< S + x$Cr$ where S denotes subsistence. As required later for estimation purposes, subsistence was measured as the market value of home-produced household consumption averaged over the two years 1972–73 and 1973–74. While 1972–73 was a slightly better than normal year in Canindé, 1973–74 was a somewhat bad year due to floods.

Risk Attitude Coefficient Estimates

Depending on whether his certainty equivalent is greater than, equal to, or less than the ex-

Table 2. Certainty Equivalents of Risky Prospects with Subsistence Assured

	Small Owners			Sharecroppers		
Attitude to Risk	Certainty Equivalent (S = subsistence)	Frequency Absolute	Frequency Relative (%)	Certainty Equivalent (S = subsistence)	Frequency Absolute	Frequency Relative (%)
	$< S$ + 2000Cr$	20	35.7	$< S$ + 1000Cr$	13	27.7
	S + 2250	1	1.8	S + 1300	1	2.1
Risk averse	S + 2750	8	14.3	S + 1700	4	8.5
	S + 3000	1	1.8	S + 1900	9	19.2
	S + 3250	9	16.1			
Risk neutral	S + 3500	5	8.9	S + 2000	4	8.5
	S + 3625	6	10.7	S + 2100	6	12.8
Risk preferring	S + 3875	4	7.1	S + 2300	10	21.2
	$> S$ + 4000	2	3.6			
Total		56	100.0		47	100.0
Would not answer		3			1	
Not available		4			8	
Excluded[a]		3			8	
Total sample size		66			64	

Note: For owners the risky prospect was S + Cr$4200 with probability 0.75 and S + Cr$1400 with probability 0.25; for sharecroppers, it was S + Cr$2400 with probability 0.75 and S + Cr$800 with probability 0.25.

[a] These respondents were judged by the interviewers either not to have understood or not to have properly tried to answer the questions.

pected value of the risky prospect, each sample farmer can be classified as risk preferring, risk neutral, or risk averse. On this basis, table 4 summarizes the distribution of risk attitudes expressed by the sample members of the two tenure groups for the two risk situations studied. These data show that a majority, but by no means all, of the farmers exhibited risk aversion and that this was more so when subsistence was at risk, and that risk aversion was more common among small owners than among sharecroppers.

Passing to more formal analysis of the farmers' responses, we consider the implications of assuming that the farmers' choices can be modeled via the unidimensional utility functions of equations (1), (2), and (3), with argument of the form X = Cr$\$(S + x)$ thereby implying perfect substitution between cash and the market value of subsistence. The mean-standard deviation function of equation (1) is of interest because, as shown by Hazell and Scandizzo, its linear form makes it extremely convenient in sectoral modeling. Indeed, the genesis of the present study lay in the desire to obtain a sample-based estimate of the average value of the population risk coefficient α to be used in a sectoral pro-

Table 3. Risky Prospects and Their Certainty Equivalents with Subsistence at Risk

Small Owners: Risky Prospect P = 0.75	P = 0.25	Certainty Equivalent	Frequency Absolute	Frequency Relative (%)	Sharecroppers: Risky Prospect P = 0.75	P = 0.25	Certainty Equivalent	Frequency Absolute	Frequency Relative (%)
S + 7000	$S/2$	$< S$	18	32.1	S + 7000	$S/2$	$< S$	1[a]	2.1
S + 6500	$S/2$	$\approx S$	5	8.9	S + 4500	$S/2$	$< S$	9	19.1
S + 5500	$S/2$	$\approx S$	4	7.1	S + 3000	$S/2$	$\approx S$	10	21.3
S + 5000	$S/2$	$\approx S$	2	3.6	S + 2500	$S/2$	$\approx S$	1	2.1
S + 5000	$S/2$	$\approx S$ + 500	7	12.5	S + 2500	$S/2$	$\approx S$ + 500	11	23.4
S + 5000	$S/2$	$\approx S$ + 1000	1	1.8	S + 2500	$S/2$	$\approx S$ + 1000	1	2.1
S + 5000	$S/2$	$\approx S$ + 1500	2	3.6	S + 2500	$S/2$	$\approx S$ + 1500	4	8.6
S + 5000	$S/2$	$> S$ + 2000	16	28.6	S + 2500	$S/2$	$> S$ + 2000	10	21.3
S + 2500	$S/2$	$> S$ + 2000	1[a]	1.8					
		Total	56	100.0				47	100.0

[a] This sharecropper (owner) was mistakenly asked the set of questions for owners (sharecroppers).

Table 4. Distribution of Risk Attitudes by Tenure Group and Risk Situation Based on Raw Responses

Risk Attitude	Subsistence Assured		Subsistence at Risk	
	Owners	Sharecroppers	Owners	Sharecroppers
	%			
Aversion	70	58	87	79
Neutrality	9	8	0	0
Preference	21	34	13	21

gramming model of northeast Brazil. The mean-variance function of equation (2) with its quadratic form has also been commonly used in risk analysis. Like the mean-standard deviation model, it is subject to criticism on both economic and psychological grounds. However, extra caution is warranted in the present instance. Because of the estimation procedure that must be used, it is not guaranteed that the fitted quadratic is monotonically increasing within the range of the risky prospect considered. This and the other criticisms applicable to the two-moment models of equations (1) and (2) do not apply to the exponential utility function of equation (3) which, a priori, we consider provides the fairest estimates of risk attitudes across the sample because it is nonlinear, monotonically increasing, and allows for moments beyond the mean and variance.

For all three utility function models, estimation of their risk attitude coefficient was based on solution of the relationship that the utility of a risky prospect is equal to the utility of its certainty equivalent. With subsistence assured, the solution of this relationship is independent of S for the mean-standard deviation and exponential models. With subsistence at risk, S must be taken into account for all three models. Since we are assuming a unidimensional utility model, rationality implies that a risky prospect's certainty equivalent can not lie outside the range of the risky prospect. Accordingly, for those respondents for whom questioning was not pursued sufficiently to fully establish certainty equivalence, we have assumed that their certainty equivalent lay half-way between where questioning ceased and the limit implied by the risky prospect.

The sample mean and standard deviation of the estimated risk attitude coefficients are listed in table 5 for each of the twelve sets of estimates covering the two tenure groups, two risk situations and three utility models. Based on the fractile rule (Mood and Graybill, p. 405), figures 1, 2, and 3, respectively, present the smoothed cumulative probability distributions for the risk attitude coefficients α, β and γ for each tenure group under each risk situation.

Model Comparisons and Implications

Except for sharecroppers under the exponential model, comparison of the average sample values of the coefficients (table 5) suggests that both owners and sharecroppers are on average more risk averse when subsistence is at risk than when it is not. Likewise, except

Table 5. Sample Means and Standard Deviations of Estimated Risk Attitude Coefficients by Tenure Group, Risk Situation, and Utility Model

Utility Model	Small Owners (n = 56)		Sharecroppers (n = 47)	
	Subsistence Assured	Subsistence at Risk	Subsistence Assured	Subsistence at Risk
Linear (α)	−0.61	−1.01	−0.44	−0.86
	(0.69)	(0.71)	(0.80)	(0.77)
Quadratic ($10^3\beta$)	0.01	−0.06	0.40	−0.04
	(0.23)	(0.11)	(1.80)	(0.27)
Exponential ($10^3\gamma$)	−1.62	−2.90	−3.46	−2.72
	(2.99)	(4.31)	(6.67)	(3.68)

for the exponential model with subsistence assured, owners appear on average to be more risk averse than sharecroppers. Given that the subsistence at risk situation is the one operative in the real world, it is interesting that (using the population proportions of table 1) the weighted average value of the mean-standard deviation coefficient with subsistence at risk for owners and sharecroppers taken together is -0.9. This population estimate matches well with the figure of -1.0 estimated for northeast Brazil by Kutcher and Scandizzo using parametric sectoral programming and by Scandizzo using econometric analysis.

The above comments are qualified by the fact that they are based only on comparisons of the means of the estimated risk coefficients. More complete appraisal is given by the distributions of figures 1, 2, and 3. These give a somewhat less clearcut picture. The α distributions of figure 1 indicate that the mean-standard deviation model provides the greatest discrimination between the four sets of estimates. The four α distributions have quite different median values and, overall, the location of the distributions strongly supports the hypotheses that owners are generally more risk averse than sharecroppers and that both tenure groups are more risk averse when subsistence is at risk. Moreover, for both tenure groups with subsistence at risk, the mean-standard deviation model suggests at least 30% of the population is strongly risk averse ($\alpha < -1.5$). Both the mean-variance and exponential coefficient distributions of figures 2 and 3 respectively have median values that differ relatively little between either the two tenure groups or the two risk situations. However, whereas the distributions of the mean-variance model coefficients are strongly positively skewed, those for the exponential model are negatively skewed. As in the mean-standard deviation case, the mean-variance model's distributions of figure 2 support—though not so clearly—the hypothesis of greater risk aversion when subsistence is at risk. But it does not support the hypothesis of owners being more risk averse than sharecroppers with subsistence at risk; in this case the mean-variance model implies that for some 75% of sharecroppers there is a greater likelihood of risk averse behavior than there is for owners.

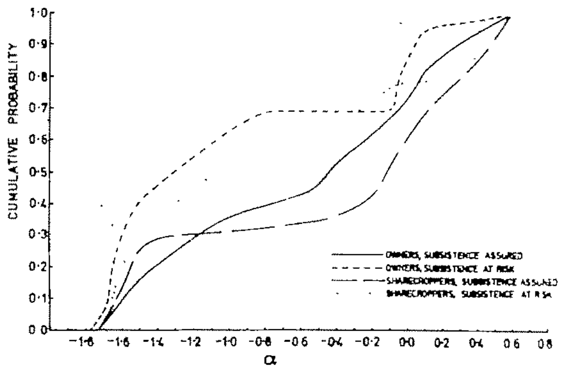

Figure 2. Cumulative probability distributions of risk attitude coefficient estimates for mean-variance model

Turning to the exponential coefficient distributions of figure 3, owners are indicated as becoming slightly more risk averse when subsistence is at risk; but this is not so for sharecroppers amongst whom some 30% are indicated as being more likely to be less risk averse when subsistence is at risk than when it is assured, i.e., a 'go for broke' reaction. Too, comparing owners and sharecroppers with subsistence at risk, there is no great difference

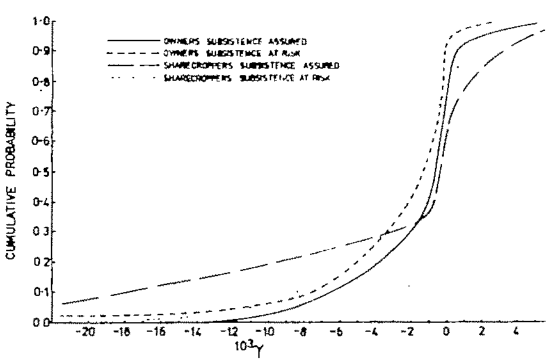

Figure 1. Cumulative probability distributions of risk attitude coefficient estimates for mean-standard deviation model

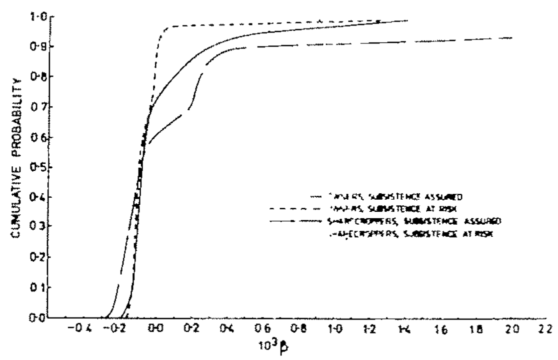

Figure 3. Cumulative probability distributions of risk attitude coefficient estimates for exponential model

between them—though, if anything, the coefficient distribution for sharecroppers depicts greater risk aversion except at the tails of the distribution. Thus, insofar as the exponential utility model is to be preferred on a priori theoretical grounds relative to the mean-standard deviation and mean-variance models, it appears there is not strong evidence for any great difference in risk attitudes between owners and sharecroppers, nor for any really substantial shift in the distribution of risk attitudes between the situations with subsistence assured and subsistence at risk. These conclusions are not in conflict with the data of table 4. Rather, in terms of making judgments about peasant farmers' behavior in the face of risk, they highlight the need to take account of the size distribution of risk attitudes and not merely of the categorization into risk averters and risk preferrers. Further, the contrasts between figures 1, 2, and 3 strongly suggest that any conclusions about population risk attitudes are highly contingent, in a unidimensional utility context, upon the type of utility function fitted.

Influence of Socioeconomic Characteristics

The nonnormal shape of the distributions of the estimated risk parameters suggest that, apart from random components, the socioeconomic characteristics of the sample farmers may account for some of the variation in risk attitude within each tenure group and risk situation studied. To investigate this hypothesis, we singled out four socioeconomic variables for which data were available, viz., the farmer's age, income, household size, and ethical attitude to betting. We also considered as a potential explanatory variable the "risk" (as measured by two alternative functions of its variance) implicit in the final risky prospect considered by each respondent within each risk situation. As to the dependent variable, we first adopted a utility-free approach by using the risk premium (i.e., the risky prospect's expected value minus its certainty equivalent) as a monetary measure of risk attitude. Subsequently we adjusted the specification of the regression model to accommodate specific forms of utility functions.

Both the utility-free and the utility-specific regression models are comprised under a general form that can be written as a linear equation relating the risk premium requested by the ith individual to (a) the risk of the prospect presented to him in the experiment, (b) a socioeconomic component, and (c) an additive random disturbance. Algebraically,

$$\eta_i = f_1(R_i) + f_2(\mathbf{W}_i) + u_i, \tag{4}$$

where η_i is the risk premium, R_i is a measure of risk, $\mathbf{W}_i$ a vector of socioeconomic variables, f_1 and f_2 indicate linear operators, and u_i is a random disturbance with mean zero and scalar variance-covariance matrix.

The first set of models generated by equation (4) is obtained by specifying the standard deviation of the prospect presented to the ith individual as a measure of the prospect's risk. This, in turn, gives rise to the following two submodels:

$$\eta_i = a_0 + a_1 V_i^{\frac{1}{2}} + a_2 Y_i + a_3 A_i + a_4 F_i + a_5 z_i + u_i, \text{ and} \tag{5}$$

$$\eta_i = a_1 V_i^{\frac{1}{2}} + u_i. \tag{6}$$

In equation (5) the socioeconomic component has been specified as consisting of the net total income Y_i of the household in 1974–75, the age of the farmer A_i, the household size F_i, and a dummy variable z_i taking a value of one if gambling is regarded as immoral and zero otherwise. In equation (6), on the other hand, the effect of the socioeconomic variables has been assumed to be nil (i.e., $f_2(\mathbf{W}_i) = 0$). In both equations, V_i indicates the variance of the final risky prospect considered by the ith farmer.

The second set of models differs from those of equations (5) and (6) in that the measure of risk adopted is defined as

$$R_i = E(X_i^2) - C_i^2 = E_i^2 + V_i - C_i^2, \tag{7}$$

where X_i is the random prospect facing the ith individual, E is the expectation operator, $EX_i = E_i$, and C_i is the certainty equivalent of X_i. This measure of risk is a linear function of the variance of the random prospect, tends to zero as this variance tends to zero, and coincides with the variance as the requested risk premium goes to zero. In the quadratic utility framework of equation (2), it also has the property of being equal to the risk premium divided by the risk aversion coefficient. Substituting this expression into the general form of equation (4) thus yields analogously to equations (5) and (6):

$$(8)\quad \eta_i = b_0 + b_1R_i + b_2Y_i + b_3A_i + b_4F_i + b_5z_i + u_i, \text{ and}$$

$$(9)\quad \eta_i = b_1R_i + u_i.$$

The four equations (5), (6), (8), and (9) propose alternative ways of interpreting the survey experiment as one of drawing out explicit risk premia and risk attitude characteristics of the population under the hypothesis that nonstochastic individual differences arise only from 'uncontrolled' socioeconomic differences. Within such an interpretation two approaches are possible. First, we may regard the specified regressions in a utility-free context. In this case, equations (5) and (8) can be used, while no special interpretation is placed on their parameters. Second, we can interpret equations (5) and (6) in the context of the mean-deviation utility model and equations (8) and (9) in the context of the quadratic utility model. In this case all equations provide single value estimates of the population risk attitude parameter (the coefficient of the risk variable). The risk attitude coefficients in equations (5) and (8), however, can be interpreted as 'marginal' parameters of risk aversion (preference), since

$$\partial\eta_i/\partial R_i = \begin{cases} \partial\eta_i/\partial V_i^{\frac{1}{2}} = a_1 \text{ in equation (5)} \\ \partial\eta_i/\partial(E_i^2 + V_i - C_i^2) = b_1 \text{ in equation (8).} \end{cases}$$

Equations (6) and (9), on the other hand, can be considered as restricted forms of equation (4) with $f_2(\mathrm{W}_i) = 0$. They provide direct estimates of the α and β parameters of equations (1) and (2):

$$\eta_i/R_i = \begin{cases} a_1 = \eta_i/V_i^{\frac{1}{2}} = -\alpha \text{ from equation (6)} \\ b_1 = \eta_i/(E_i^2 + V_i - C_i^2) = -\beta \text{ from equation (9).} \end{cases}$$

Within each specification of the measure of risk adopted, therefore, and quite apart from the two alternative utility models, the unrestricted equations (5) and (8) provide marginal measures of risk aversion, while the restricted equations (6) and (9) provide average measures. For the two tenure groups, table 6 presents least squares estimates of equations (5), (6), (8), and (9) as indexed at the bottom of the table, contrasting the subsistence assured with the subsistence at risk situation.

As in the case of the individual data, major differences appear to exist between the values of the parameters measured for the case of subsistence assured and the case of subsistence at risk. While for sharecroppers these differences extend to the entire equations, the marginal risk aversion parameters estimated for owners under the two sets of circumstances are not significantly different from one another at a 5% confidence level. This comparison is only possible for the quadratic utility unrestricted model of equation (8), represented by estimated equations A.1, A.3, A.6, and A.8 of table 6, since no results could be obtained for the other two models in the case of subsistence assured.

For the more realistic hypothesis of subsistence at risk, equations A.2 and A.7 in table 6 provide some of the "best" statistical fits and perhaps the intuitively most appealing results. According to these equations, for both owners and sharecroppers an increase in the riskiness of the random prospect induces an increase in the required risk premium. A similar association appears for variables such as ethical beliefs against gambling, aging, and, for owners, an increase in household size. Conversely, and in conformity with the intuitive evidence presented by Arrow (chap. 3), an income increase causes the requested risk premium to fall.

Equations A.3 and A.8 differ from A.2 and A.7 only in the specification of the risk measure and, within each tenure group, respectively show similar values of the estimated coefficients whenever these are significantly different from zero. As for A.2 and A.7, comparison between tenure groups indicates somewhat stronger results for the owners' subsample, i.e., A.3. For both tenure groups and both risk situations, the quadratic risk attitude coefficient b_1 of equation (8) is highly statistically significant and implies a larger risk premium as risk increases—and this is more so with subsistence at risk. Though not statistically significant, the only other consistent effect with the model of equation (8) is an increase in risk premium as household size increases. These results are analogous to those obtained for the linear utility model of equation (5), equations A.2 and A.7 in table 6, and show much the same pattern of signs and significance except for the dummy variable representing ethical attitude to gambling for the

Table 6. Least Squares Estimates of Equations (5), (6), (8), and (9) by Tenure Group and Risk Situation

		Small Owners					Sharecroppers				
Independent Variable		Subsistence Assured		Subsistence At Risk			Subsistence Assured		Subsistence at Risk		
Constant		2401*** (445)	−9687*** (1808)	4324** (1423)	—	—	314* (254)	−2103** (727)	243 (665)	—	—
Income	Y_i	0.12*** (0.02)	−0.28*** (0.08)	−0.31*** (0.08)	—	—	0.06* (0.03)	−0.11 (0.08)	−0.08 (0.09)	—	—
Age	A_i	−12.21** (5.78)	34.95* (17.86)	37.16* (17.50)	—	—	—0.83 (4.11)	3.32 (9.98)	2.52 (100.70)	—	—
Household size	F_i	22.80 (22.49)	124.40 (70.99)	110.37* (69.49)	—	—	20.13 (31.67)	−17.57 (51.14)	19.32 (54.75)	—	—
Gambling attitude	Z_i	12.31 (92.42)	427.52 (405.74)	308.63 (395.04)	—	—	23.60 (111.32)	591.40* (266.85)	−581.94* (286.39)	—	—
Standard deviation	$V_i^{1/2}$	—	3.93*** (0.46)	—	1.14*** (0.09)	—	—	2.71*** (0.30)	—	1.10*** (0.11)	—
Second moment minus squared certainty equivalent	$(E_i^2 + V_i - C_i^2)^a$	0.88*** (0.08)	—	0.92*** (0.08)	—	0.39*** (0.03)	0.15*** (0.02)	—	0.69*** (0.08)	—	0.62*** (0.04)
R^2		0.72	0.61	0.62	0.28	0.42	0.69	0.71	0.67	0.40	0.61
Equation number		A.1	A.2	A.3	A.4	A.5	A.6	A.7	A.8	A.9	A.10
Parent equation in text		(8)	(5)	(8)	(6)	(9)	(8)	(5)	(8)	(6)	(9)

Note: Standard errors in parentheses. Asterisks denote significance: *** for above 0.1%; ** for between 0.1 and 1%; * for between 1 and 5%.
[a] This measure of risk attitude has been scaled up by 10^3.

case of sharecroppers with subsistence at risk. The differing signs between risk situations for the effect of income, age, and gambling attitude on the size of the risk premium further support the data of table 4 in suggesting a qualitative difference in the behavior of the respondents in the two risk situations. When subsistence is not at risk, the extent of risk aversion increases rather than decreases with income for both tenure groups, whereas the reverse occurs with regard to family size.

Comparison of the regression-based estimates of marginal risk influence of equations A.4, A.5, A.9, and A.10 of table 6—i.e., the $-a_1$ and $-b_1$ values in equations (6) and (9) of the text—with the sample mean α and β values of table 5 shows that the regression estimates imply marginal degrees of risk aversion consistently in excess of average values; the percentage increases in risk premia required to offset a given percentage increase in risk (the risk premium 'elasticities') are thus greater than unity.

Although some of the socioeconomic variables proved to have a significant effect on the elicited certainty equivalent in both the linear and the quadratic utility cases, we also can compare and statistically test the difference between the estimates of the risk coefficients given by the restricted equations with the sample means of α and β in table 5. Using paired t tests, in the case of the linear model this comparison yields the result that all estimated coefficients for the two tenure groups under subsistence at risk do not significantly differ from each other or from unity for any reasonable confidence level. For the quadratic case, however, the regression estimates of β are significantly lower (i.e., more negative) than the sample average values, further evidencing the vagaries of using different utility function forms.

Conclusions

The broad conclusions we draw from this empirical study of peasant risk attitudes in northeast Brazil can be briefly summarized: first, most but not all peasants are risk averse; second, risk aversion tends to be more common and perhaps greater among small owners than among sharecroppers; third, in an expected utility context, the distribution of peasant risk attitude coefficients is diverse and not necessarily well represented by an average population value; fourth, level of income and perhaps other socioeconomic variables influence peasants' attitudes to risk. Finally, we believe our analysis has shown that it is possible via simple but purposive questioning to elicit meaningful information on peasant attitudes pertinent to rural development.

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A Model of Crop Selection in Semi-subsistence Agriculture and an Application to Mixed Agriculture in Fiji

A. John De Boer and Satish Chandra

The vast majority of the world's farmers operate as semi-subsistence producers. Models of fully subsistence agriculture are modified to allow a two-goods analysis of cash crop and staple crop production. A further extension allows comparisons between two groups of farmers possessing different production functions for their respective staple crops. Production possibility curves are constructed for each group of farmers and an empirical test formulated. Empirical results confirmed the hypothesized behavioral relationships which would give rise to the observed differences in resource allocation and resource productivity between Indian and Fijian farmers operating within a similar agricultural environment.

Key words: allocative efficiency, Fiji, semi-subsistence agriculture.

Analysis of allocative efficiency in traditional agriculture often highlights intragroup performance differences. Typically, production functions are estimated for all farmers and dummy variables separate intragroup effects, or production functions are estimated for each group of farms and results are compared. These procedures are often successful in identifying productivity differentials but seldom explore underlying factors that give rise to these differences—factors which should help identify household production-consumption behavior, the subjective equilibrium of peasant farms, or the factors underlying the cash-subsistence-crop proportions. Despite the existence of numerous theoretical treatments of the latter three topics, the link between the results of allocative efficiency studies and farm household behavior is seldom established. Studies concentrating on the subjective equilibrium of peasant economies include those of Mellor, Sen, Nakajima, and Nowshirvani; and on the food surplus-producing potential of farmers when a pure subsistence agriculture is exposed to trade are Fisk 1962, 1964, 1971; Shand; Fisk and Shand; Stent and Webb.

We attempt in this paper to provide a policy-oriented approach to allocative efficiency studies by looking at those specific aspects of farmer behavior that give rise to differences in production function results. More specifically, we develop a simple two-goods model following Stent and Webb's approach to the allocation of resources between subsistence and cash crops. This model helps in part to explain the substantial differences in allocative efficiency results obtained from a study of Indian and Fijian farmers on Fiji.

This paper consists of five sections. First, we present the results of applying conventional Cobb-Douglas production functions. Second, we develop a simple two-goods model of the village economy by aggregating all agricultural production into staple crops or cash crops based on patterns of dietary preference and cash sales. Third, energetic analysis establishes the basis for the differential subsistence crop production functions between the groups. Fourth, we use the model to advance several hypotheses regarding observed differences in production patterns and resource use between the Fijian and Indian farmers operating under similar environmental conditions.

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Finally, we test the alternative hypotheses and apply the results to agricultural policy questions.

Allocative Efficiency Results

A series of Cobb-Douglas production functions were fitted, using a two-year, cross-section sample of farm management data collected during 1970–72 in the Sigatoka Valley, Fiji. (Data, referred to as "Farm Management Survey Data, 1970–72" where appropriate, are also used in the subsequent analyses.) Sampling was based on race, region, soils, and land tenure. Separate functions were estimated for each group using data combined over both years. The following function was established: $Y = AX_1^{\alpha_1}X_2^{\alpha_2}X_3^{\alpha_3}X_4^{\alpha_4}e^u$, where Y is gross output of crops ($); X_1 is total arable farm area in hectares (ha); X_2 is family labor plus hired labor (adult man-days); X_3, capital service flow deflated by the crop time ratio ($); and X_4, current expenses ($). The crop time ratio is Σ (cropped area) by month divided by (total area) by month. It is used to deflate capital flows calculated per farm on a use-intensity basis.

A man-hour of hired labor was assumed equal in productivity to a man-hour of family labor. The subsistence crops had well recognized market values because small surpluses of these crops were often sold and a regular market for these crops existed.

The results (table 1) indicate that, in general, Fijian farms do not apply enough of any resource while Indian farms apply far too much labor on too little land.[1] However, the land market is imperfect due to institutional constraints on land tenure, severely limiting the access of Indian farmers to additional land. In addition, capital is limited. Therefore, constraints on the availability of land and capital were introduced into the profit functions (Vandenborre and McCarthy) and the optimal input levels thus calculated are given in table 2. With capital limiting, the results are consistent with recommendations based on table 1, but with land fixed (column 4) the results indicate that both groups should decrease labor use with labor valued at the market wage rate. This indicates a "wage gap" phenomenon (Sen) where the real cost of labor, as subjectively valued by the farm household, is less than the wage rate for hired labor. The results also indicate a large difference in magnitude of this apparent "misallocation of labor," because Indian farmers apply labor at about 4.5 times the optimal rate (column 4), while Fijians apply about 25% too much. This is despite the fact that Indian farmers have higher inputs of both capital and current expenses.

[1] Several specific schools of criticism have developed against the production function approach to the study of allocative efficiency. Roughly, there is a "risk" school (Dillon and Anderson, Weins), a "statistically unsound" school (Nerlove, among others), and a "conceptually unsound" school (Duloy, Massell and Johnson, Shapiro, Wise and Yotopoulos). Our purpose is not to defend our approach against each school; indeed some aspects of these criticisms are valid against virtually any study of allocative efficiency.

Table 1. Production Function Results for Fijian and Indian Farms: Both Years Combined Data

	Variables (X_i)				
	Land	Labor	Service Flow of Capital	Current Expense	
Fijians:					
Const. = 13.36, R^2 = .78, n = 50					
Production elasticities	.140	.336*	.285**	.123*	$\sum_{i=1}^{4} Xi = .884$
	(1.24)	(1.71)	(2.10)	(1.71)	
Marginal value products (*MVP*)	36.00	.29	4.60	1.90	
MVP/P	7.20	1.50	4.60	1.90	
Indians:					
Const. = 17.34, R^2 = .86, n = 73					
Production elasticities	.461**	.091	.377**	.282**	$\sum_{i=1}^{4} Xi = 1.21$
	(4.56)	(.65)	(5.10)	(4.62)	
Marginal value products (*MVP*)	159.20	.08	5.10	2.90	
MVP/P	11.10	.44	5.10	2.90	

* Significantly different from 0 at the 10% level.
** Significantly different from 0 at the 5% level.

Table 2. Optimum Resource Allocation: Fijian and Indian Farms

Columns	Sample Mean Level ha^{-1} (1)	Ratio of Marginal Value Product to Marginal Cost (2)	Optimum Resource Allocation with Limited Capital (3)	Optimum Resource Allocation with Limited Capital and Land Area (4)	Optimum Resource Allocation with Limited Capital and Labor Fixed (5)
	($)		($)	($)	($)
Fijian farms					
Land (A)	172	7.18	44	172	56
Labor (L)	59	1.53	106	48	59
Capital (C)	19	4.61	90	41	115
Current expense (E)	29	1.92	39	18	49
Total	279		279	279	279
Indian farms					
Land (A)	261	11.09	151	261	134
Labor (L)	70	0.44	30	16	70
Capital (C)	22	5.14	123	68	110
Current expense (E)	43	2.96	92	51	82
Total	396		396	396	396

Note: Production function coefficients are given in table 1.

Part of the difference undoubtedly is due to differences in family size (5.54 for Fijians, 7.1 for Indians), and a higher expenditure of labor per active worker in response to a larger family size is to be expected (Sen). Given the demographic composition of the two groups, the number of active workers available for farm labor was similar because Indian families had a higher proportion of children not engaged in farming. The much different proportions of resources devoted to cash crops (as opposed to susbsistence crops) by the Indian farmers are not readily explainable by the existing subjective equilibrium models of Mellor, Sen, or Nakajima. An alternative model developed to explain the transition from pure subsistence to a partially commercial agriculture provides an alternative explanation.

The Subsistence Affluence Model

The concept of subsistence affluence was first advanced by Fisk in 1962 to define the supply of labor and other factor inputs in excess of that required to meet the demand ceiling for food and other subsistence household needs in a pure subsistence economy. These surplus resources could be used for increased food production as population increased or be diverted to cash crop production as markets developed (Fisk 1964). This model was extended by Shand, who included indifference curve analysis. A further extension by Stent and Webb considered labor input as adding positive utility up to a point. Results were discussed for single and multiple products, traded and untraded products, as well as for an analysis of taxation effects.

Preliminary Remarks

To apply the subsistence-affluence model to the two groups, consider a simple two-good agricultural economy consisting of a staple crop (S_c) and a cash crop (C_c). Both groups produce the cash crop with identical production functions, but one group (F) produces the staple crop much more efficiently (in a technical sense) than the other (I) group. Given smooth diminishing (but not negative) returns production functions, the production possibility curves for the two groups—each possessing fixed resource bundles—will look like those of figure 1. The production possibility curves (PPCs) are RQ and TQ for the I and F groups, respectively. The production unit can represent a family, group of families, or villages, as long as the underlying environmental conditions are the same. Next, assume that terms of trade between S_c and C_c are sufficiently unfavorable so the sale of C_c for purchase of S_c is unattractive. This is the assumption made by Shand; and, given the high transport cost of bulky staple crops, it probably fits the case at hand. Purchases of food from the cash sector are common but are concentrated on items not produced locally, such

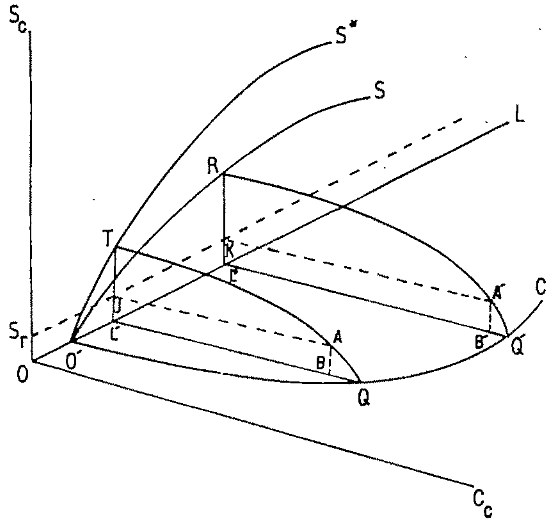

Figure 1. Production possibilities with fixed inputs

as tinned fish and wheat flour, and not on staple crops. Let *OP* represent the (biologically determined) demand for the staple crop (initially assumed equal for each group).

Given this scenario, points *A* and *B* represent a constrained maximum, or "stinted," solution (Stent and Webb) for the *F* and *I* groups, respectively, while point *C* represents "subsistence affluence" (model 1). Several possibilities exist for point *C*, although neoclassical economics would exclude points off the contract curve. Points such as *C* are assumed away, since a PPC using less resources could always be constructed which would pass through point *C*. Stent and Webb assume that up to a point working in the fields provides positive utility in addition to the utility provided by the consumption of C_c and S_c, so point *C* can then be obtained by nonuse of some of the fixed resource bundle assumed in the construction of PPCs *TQ* and *RQ;* in their case, garden land. Another possibility would be to treat point *C* as a consumption bundle where *CB* or *CA* of C_c is wasted or given away. Point *C* would then represent a socially constrained level of cash required from the production of C_c, a sort of Zen road to bliss (Sahlins). Another possibility of relevance to Fijians arises due to the community-sharing practice in Fijian villages where neighbors, relatives, and friends have some degree of reciprocal rights to a household's possessions. In these circumstances, a move from *C* to *A* in figure 1 would be of little material benefit to the household itself.

If it is observed that both groups of farmers possess similar resource endowments, have similar staple crop needs, and produce similar quantities of staple crops, but the group represented by *RQ* (group *I*) is in fact producing much larger quantities of cash crops than the group with the PPC *TQ* (group *F*), then two possibilities exist. First, group *F* could be characterized by a subsistence-affluence situation (point *C*) in figure 1.[2] The second possibility is to allow for production on the PPC and variable labor inputs.

Production and Consumption Possibilities with Variable Labor Inputs

If both groups produce in a constrained maximization manner, then another possibility is that the *I* group may be applying labor more intensively to the nonlabor inputs. To examine this case graphically, a unique production relationship must be defined for each group between labor, C_c and S_c. Figure 2 assumes the previous production relationships plus the proviso that both cash crop production ($O'C$) and staple crop production ($O'S$ for group *I*, $O'S^*$ for group *F*) begin at O' on the labor axis (OL); the PPC will then appear as TQ for a labor input of $O'L'$ for group *F* and RQ' for a labor input of $O'L''$ for group *I*. Assuming for the moment that staple crop requirements are independent of labor used, then OS_r ($= L'J = L''K$) is the staple crop demand common to each group. Under constrained maximizing behavior, production occurs at *A* for group *F* and *A'* for group *I*. (The movement of a farm from *A* to *A'* may result from changing indifference relationships (not shown here) between labor and goods purchased with the cash crop.) Because $L''B' > L'B$, this solution is also consistent with observed behavior between the two groups. Movements along the $O'L$ axis, by allowing the PPC to expand, can increase the production of cash crops and, by introducing utility curves with labor inputs and cash crops as arguments, would allow us to determine the equilibrium point for labor, S_c

[2] A third possibility seems obvious: the ratio of the rate of indifference between work disutility and goods utility (food crops and money from cash crops) systematically differs between the groups, so the *I* group consistently places a lower value on the real cost of labor (Mellor, Sen). This argument is quite different to that required for the existence of an interior bliss point, however. The limited aspirations models of Mellor and Sen are concerned with equilibrium points on a production function, i.e., on the PPC in figure 1. The bliss point *C* in figure 1 requires a positive utility attached to labor (up to a point), not a disutility. Equilibrium analysis on the PPC is carried out in model 2.

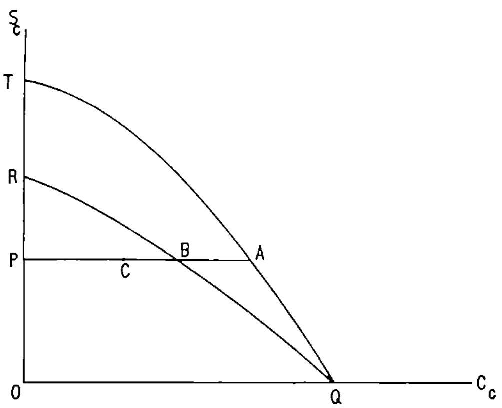

Figure 2. Production possibilities with variable labor inputs

and C_c. This could also be represented conceptually as a ratio between the production of cash crops and the labor used, e.g., $\frac{L''B'}{O'L''}$ for group I and $\frac{L'B}{O'L'}$ for group F. To carry out empirical tests on this model using the individual household as a unit of observation, figure 2 must be extended to allow intrahousehold variations in the demand for the two goods caused by factors such as family size and labor expended.

Figure 3 (model 2) represents a series of PPCs for group F. As the labor input per family increases, so does the stable crop requirement (from $L'S'$ at $O'L'$ to $L''S''$ at $O'L''$). This can result from a greater requirement per worker as his effort rises for a fixed family size or a larger labor input associated with larger families. This increased S_c requirement can be obtained from the same input of labor ($O'L'$) but at a sacrifice of QQ' cash crop production, or by increasing the labor input to $O'L''$ to allow simultaneous expansion of cash crop

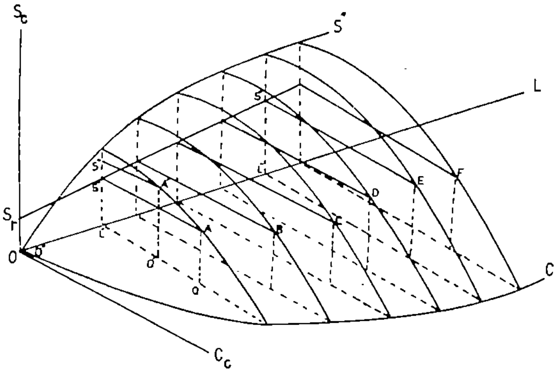

Figure 3. Production and consumption possibilities for a group

production, or by any intermediate combination. Because it seems highly unlikely that the family demand for cash falls as family size increases, an expansion of the PPC sets would seem likely.

By assumed constrained maximizing behavior, points such as $A, B, \ldots, F$ in figure 3 represent the optimal production proportions for the two products as well as the optimal applications of labor. By superimposing the expansion surface for the I group of farmers, a distinctly different set of points should be observed if model 2 holds. This is the basis of the empirical tests carried out later, but the empirical basis for the differential subsistence crop production relationships is discussed first.

Production Relationships

Staple Crop Sector

Staple crop production and consumption patterns of the two groups are much different. Fijians rely heavily on starchy root crops such as cassava, sweet potato, taro, and yams; Indians rely on rice, pulses, green beans, and eggplants. Staple food crop production for each group was aggregated in energy terms (in kilojoules [kj]) because these crops are consumed primarily, although not exclusively, for the provision of energy. Therefore, the relationships $O'S$ and $O'S^*$ in figure 2 are in terms of food energy produced from various labor inputs. The underlying reason for this differential response can be summarized by an analysis of energetic efficiency. A key element in this analysis is the efficiency ratio (E) representing the edible energy yield of crops (kj) divided by the kj of energy expended by man, draft animals, and fossil fuels to attain that yield (Black). Photosynthetic energy generated by the plants is excluded. Thus, the higher the E of a crop, the more efficient it is in using energy inputs to produce food energy under a given technology and the larger the output response (in energy terms) from incremental labor inputs. (The energy inputs from draft animals and fossil fuels were similar between the two groups; thus, the ratios are a good indication of the relative efficiency of the farmers' labor in producing energy from crop production. Energetic efficiency should not be confused with economic efficiency [Edwards], although economic factors influence energetic inputs [Chandra, De Boer, Evenson].) The

efficiency ratios calculated for the major staple crops are shown below:

Fijian Crops	E Ratio	Indian Crops	E Ratio
Cassava	52	Rice	9
Sweet potato	60	Pulses	11
Taro	21	Green beans	4
Yams	66	Eggplant	10

The E ratios of Fijian staple crops are much higher than those of the Indians, because the Fijians depend on the more energetically efficient root and tuber crops. The highly efficient energy storage system of these crops (Coursey and Haynes) provides a higher yield of kj per hectare and per man-hour expended under the similar production technologies utilized. These results imply that the Fijian system is more efficient in terms of the labor input to energy output ratio for staple crops. This is the phenomenon giving rise to the different PPCs of figures 1 and 2.

Cash Crop Sector

Cash crop production was aggregated into dollar values based on farm gate prices. The limited marketing of staple crops carried out by some farmers was not considered. Thus, total value of all crops marketed was not used, but only the cash sales of designated cash crops. A major factor determining quantities of cash crops produced is the differential demand for cash between the two groups; that demand differential arises for several reasons: (*a*) Most Fijian farmers do not pay land rent, while all Indian farms operate on leased land for which cash rent is payable. (*b*) The village communal system of the Fijians does not provide as much incentive for individual advancement through competition for wealth or capital items. The Indian social structure, on the other hand, places more emphasis on self-improvement and capital accumulation. (*c*) Average family size of the Fijians is smaller than that of the Indians, averaging 5.6 persons compared to 7.0 persons per household on Indian farms.

We, therefore, hypothesize that if the subsistence-affluence model of farmer behavior is rejected, then Indian farmers would operate on a point such as A' in figure 2, while Fijians would operate on a point such as A.

Testing the Subsistence Affluence Hypothesis

As mentioned earlier, the situation depicted in figure 1 provides a possible explanation for the observed mix of cash crops and staple crops. One method for testing the existence of a point such as C is to test for profit maximization which, by assumption, excludes points such as C. In the context of the production function analysis outlined earlier, profit maximization implies $MVP_{X1}/P_{X1} = MVP_{X2}/P_{X2} = , \ldots ,$ $= MVP_{Xn}/P_{Xn} = 1$ in the absence of resource restrictions, or alternatively, observing these ratios equal to a constant when one or more resources are in restricted supply. Alternatively, Wise and Yotopoulos have outlined a more general procedure which does away with some of the more restrictive assumptions of earlier studies but assumes a particular form of utility function. Johnson, among others, is skeptical of the Wise-Yotopoulos test applied to general cases. The profit function approach (Lau and Yotopoulos), while assuming profit-maximizing behavior to derive the relevant parameters, conceivably could be used to test for profit maximization per se. The profit function approach relies to a large extent on the presence of variations in output and input prices facing different farmers and is thus less useful for studying a fairly homogeneous region (the case here) since input price variations within a group are relatively minor.

A more direct approach is to estimate a production frontier to obtain efficiency indices for the individual farmers in each group when the two groups are combined for the analysis. While we have assumed different S_c production functions between the groups, the difference was a result of having output expressed in kjs rather than dollars. When the outputs are weighted by prices, then the output variable between the groups can be aggregated into value produced, which is required for the frontier production approach to a multicrop situation. By combining both groups of farmers, we can systematically compare each farm to all other farms. In this way, Fijian farms are compared with all Fijian, as well as with all Indian farms. If the technical efficiency ratings of the farms in each group are similar, we can conclude that both groups are operating on similar positions on or within the production frontier, deviations from the frontier being caused by excluded variables such as management, market accessibility, soil types, and minor variations in the cropping microenvironment (Müller).

We used computation procedures outlined by Timmer and Seitz (for the constant returns to scale case), and give the technical efficiency ratings for the two-year mean of both groups

Table 3. Technical Efficiency Ratings and Gains in Gross Margins for Indian and Fijian Farms (Averages for Both Years)

	Fijians	Indians
Number of 100% efficient farms	5	5
Mean percent efficiency rating of all farms	78	76
Percentage of all farms within 15% of the production frontier	43	42
Mean percent efficiency rating of the least efficient 20% of farms	53	49
Per farm gain in gross output given the adoption of the optimum farm plan ($)	189	264
Percentage of increase on previous gross output	26	18

in table 3. (Standard statistical tests applied to the sum of the coefficients of the variables in table 1 indicated that the sum was not significantly different from one for both the Fijian and Indian functions.) These results indicate no large or systematic differences between the two groups: five Indian and five Fijian farmers were 100% efficient; 43% and 42% of Fijian and Indian farmers, respectively, were over 85% efficient; and 50% of Fijian farmers and 58% of Indian farmers were at least 75% efficient. The advantage of the production frontier approach for testing the subsistence affluence hypothesis is that the estimation procedure is not concerned about where the farmers are on the frontier, only where they are relative to an efficient frontier calculated from the existing data set. This is precisely what is required for testing the subsistence affluence hypothesis; and, since it does not appear that Fijian farms are operating consistently further away from the frontier than are Indian farmers, we can reject the subsistence affluence hypothesis as applied to Fijian farms. This also conforms with reality. In the context of the subsistence-affluence model where more cash can be obtained from the same level of input availability, a limited demand for cash does not appear to hold in Fijian agriculture where about 40% of the gross value of output of the sample farmers was sold, where purchases of food and nonfood items are common, and where cash expenditures for village social obligations are highly regarded.

Test of Model 2

By reference to figure 3, the test consists of establishing whether sets of points such as A, $B, \ldots, F$ for the two groups are significantly different. A scatter diagram of observations for S_c, C_c, and L (not shown here) indicated that the two groups followed quite different paths as hypothesized in figure 3. Statistical testing of these pathways of crop choice consists of two parts. First, within each group the relationship between the level of S_c, C_c, and L must be significant as we move to higher PPCs; i.e., the regression relationship itself must be significant. Second, because we are hypothesizing that the location of points on the PPCs are different between the two groups, the regression coefficients for S_c and C_c must be statistically different.

Following from figure 3, we assumed the level of subsistence crop production varied directly with the labor input and thus indirectly with the level of cash crop production. Consequently, S_c was used as the independent variable, while C_c (in $) and L (in man-hours) were dependent variables. Linear equations gave higher R^2 values than similar log-linear functions and were thus chosen. The relationship between S_c and L does not seem as well defined as that between S_c and C_c with each group (table 4). This would indicate that, for any level of C_c, a well-defined relationship between S_c and L was not evident. The problem would be overcome by partitioning labor use between S_c and C_c, but this would preclude the relationship depicted in figure 3.

All regressions were significant based on the F test. Slope coefficients were tested to see if they were significantly different from each other using the homogeneity of slope coefficients test described in Johnston. The computed F values showed that for the linear regressions the C_c coefficients were significantly different between the two groups. The different pathways of crop choice result from different dietary patterns. Those patterns give rise to the differential energetic relationships in the S_c sector as well as a much higher demand for cash by the Indians. This demand then pushes their crop selection PPC further along the L axis.

In summary, the performance of the two groups according to the hypotheses derived from model 2 must be regarded as significantly different. First, the relationship between the three variables is significant (the F test reported in table 4). Second, the slope coefficients between each group were significantly different indicating that the equilibrium positions (A, B, . . . , F in figure 3) between the two groups follow different paths.

Table 4. Regression Results for the Test of Model II

	Equations	
	Fijian Linear	Indian Linear
Number of observations	50	73
Constant term	6,877,700	5,895,200
C_c coefficient	8,769	4,282
t value	(6.2)[a]	(13.9)
L coefficient	1,310	−1,099
t value	(1.03)	(2.18)
R^2	.801	.815
Regression F ratio	95	154
Test of Regression Coefficients		
d.f. for F	(1,119)	
Critical F at 1% level	6.85	
Measured F	86.42	

[a] t values in parentheses.

The underlying reasons are (*a*) the difference in the efficiency of staple crop production between the two groups give a different shaped PPC for Fijians as opposed to Indians; and (*b*) different sloped utility curves give a different subjective equilibrium between L, S_c, and C_c on the PPCs. Policy conclusions are now drawn from these results.

Conclusions

As Fisk (1962, 1964, 1971), Shand, and others have shown, the efficiency with which a staple food crop is produced has a bearing on (*a*) the resources available for the production of marketable surpluses of cash crops, (*b*) the surplus labor capacity of agriculture, and (*c*) the labor absorption capacity of traditional agriculture. The analysis presented above indicates the influence that varying levels of energetic efficiency in the production of a subsistence crop can assert on crop choice, labor use, and cash income.

Fijian farm development must proceed by shifting their PPCs outward, because a move to the right along the PPCs in figure 3 is not feasible as it implies a reduction in subsistence crop consumption levels. Given the high efficiency of subsistence crop production, however, additional incremental applications of labor can be devoted almost exclusively to cash crops. The key to success is shifting their PPC outward along the L axis in figure 3. This shift can take place by increasing the Fijian's demand for cash through their greater market access and participation, or through taxation methods—although the results of taxes applied to this situation are not clear (Stent and Webb). Technical advances should be directed towards cash cropping for this group because their efficiency of subsistence crop production (in energy terms) is already high.

For the Indian farms, on the other hand, increased labor use is not the answer because labor productivity is already low on these farms. Increased access to complementary inputs (land in particular) which allow expansion of the PPCs is one possibility, while land-augmenting technical innovations would also help. The former recommendation implies the removal of some institutional restrictions on the land market. Increased efficiency in the production of staple crops would release resources for more cash crop production. An alternative may be to encourage increased specialization of crops so that increased purchases of these staples could be made from cash sales.

The approach developed here has illustrated the value of more in-depth analysis of production and consumption relationships than is normally associated with the allocative efficiency or production frontier approach to production analysis. The underlying reasons for observed mixes of output and differences in input applications are made clearer and the policy implications are made more explicit.

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The Role of Education in the Dynamics of Supply

Todd E. Petzel

This paper offers a synthesis of Nerlovian supply dynamics and the recent work on the role of education in entrepreneurial decision making. The model is tested by looking at the dynamics of soybean supply for U.S. counties from 1947 to 1973. Rates of adjustment to long-run equilibrium are found to depend on several variables, including education of the decision maker.

Key words: education and technology, expectations, supply response.

The dynamic properties of the supply of goods and services have been examined closely in the literature. Starting with the cobweb theorists and working through Nerlove's seminal 1958 study, a theory has been developed to explain the movement of prices and goods through time. Unfortunately, attention to date has concentrated largely on the appropriate econometric estimation of these time-series models, leaving the examination of the underlying economic forces at a less refined level.

The central feature of the dynamic supply model is a parameter which measures the rate of adjustment to a hypothesized long-run equilibrium. The work in this area, well reviewed in Griliches (1967) and Nerlove (1972), deals generally with obtaining efficient estimators of the rate-of-adjustment parameter. Important as this may be, little discussion has been devoted to explaining why one entrepreneur has a different rate of adjustment than another, or why firms adjust faster (or slower) in 1978 than at the turn of the century.

A growing literature stresses the importance of the decision maker's education in adapting quickly to changes in his economic environment (Schultz). This current paper unites the human capital literature with the study of supply dynamics, suggesting that economic variables, including education of the entrepreneur, play an important role in determining adjustment to equilibria.

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The Model

The model of supply dynamics used here will be similar to the one proposed by Nerlove (1958). Output is produced by the firm with a one period lag so that the market price at which the product will be sold is not directly observable.

$$(1) \qquad X_t^o = aP_{xt}^e + \Sigma b_i P_{it}^e + cP_{ft}^e .$$

Equation (1) states that the desired output in period t is a function of the expected own price, a vector of the expected prices of i, alternative outputs, and the expected costs of factors used to produce X ("e" superscript will mark expected values, while "o" superscript will denote their optimal or desired values). This output is assumed to be the profit-maximizing level in a world with no adjustment costs. All expectations are formed using information available through $t-1$.

The virtue of a dynamic model lies in the fact that it allows for the possibility of "incomplete" adjustment in any single period. If expected own price shifts upward for whatever reason, the expected reaction is for optimal output to rise. The question remains, however, what happens to actual X_t? Where there are costs of adjustment, actual output will rarely equal the optimal. Nerlove suggested that in each period actual output is changed in proportion to the difference between desired output and last period's actual output:

$$(2) \quad X_t - X_{t-1} = g(X_t^o - X_{t-1}) \; 0 \leq g < 1,$$

The parameter g in Nerlove's model was a

constant dependent only on the elasticities of supply facing the industry. The direction of this study is to allow the coefficient of adjustment greater flexibility.

Solving for X_t^o, and substituting into (1) you get:

$$(3)\quad X_t = gaP_{xt}^e + g\Sigma b_i P_{it}^e + gcP_{ft}^e + (1 - g)X_{t-1},$$

which is a relation between this period's actual output, expected prices, and last period's output.

The purpose of this study is to examine factors that may explain differences in g across firms. To understand how this mechanism may operate, it is important to examine the theoretical foundation of equation (2).

Assume a quadratic loss function of the following form:

$$(4)\quad L = a_1(X_t^o - X_t)^2 + a_2(X_t - X_{t-1})^2 \qquad a_1 > 0,\ a_2 > 0.$$

The first term on the right-hand side represents the lost profits associated with suboptimal output. The second term captures the cost of moving away from the present position. This loss function is in the spirit of work done on progress functions by Alchian and others. They point out why the long-run optimum is reached only after a dynamic adjustment period. Unfortunately, few economic forces are introduced in the theory of progress functions that could alter the dynamic adjustment path.

Since X_t^o is the profit-maximizing output, the goal is to minimize equation (4), which will maximize profits net of adjustment costs. It can be shown that when (4) is minimized, solved for X_t, and the terms are rearranged slightly, you get:

$$(5)\quad X_t - X_{t-1} = [a_1/(a_1 + a_2)](X_t^o - X_{t-1}).$$

This is, of course, the same as equation (2). Since both a_1 and a_2 are positive by definition, increases in the first will tend to increase g while increases in a_2 will tend to lower the rate of adjustment. Simply stated, when incentives go up, so will the rate of adjustment, and conversely for costs.

If the coefficients a_1 and a_2 depend on characteristics of the firm, then it is clear that differences in the rate of adjustment can be shown to be caused by differences in optimizing paths and not on ad hoc models that predict sluggishness.

The model will be tested by looking at the dynamics of the soybean supply 1947–73. The sample will consist of a cross-section of counties throughout the Corn Belt and Mid-South over this period. Soybeans were chosen as the empirical test because of phenomenal increases in plantings over this period, and because they are largely grown on family farms where the return to labor goes to the same parties as does that from capital and land. To facilitate discussion, influences on a_1 and a_2 will be described in this context.

To determine the magnitude of the profit loss term a_1 for the firm, it is sufficient to know the cost function. As one moves away from the marginal firm, profits per unit of output become positive and incentives to move to the optimal output become higher. Equation (6) includes a plausible set of factors that might be expected to influence the costs to the firm and, hence, a_1.

$$(6)\quad a_1 = a_1(E, S, Y, \epsilon_i),$$

where E is farmer's education, S is a measure of the size of farm, Y is the yield of the crop, and ϵ_i is a vector of supply elasticities for inputs into the production function.

Finis Welch's worker effect (1970) is the source of the first influence. Farmers with more education are more productive; therefore, all other things the same, the farmer's education should increase the profits of the farm. As we saw above, as absolute profits increase, so will the rate of adjustment.

The influence of farm size is dependent on the existence and direction of scale economies over the relevant range. There is no a priori supposition about the existence of these economies, so the theory is neutral on this point.

Because this model, like many other commodity supply studies, deals with acreage decisions yield is an important variable in the equation. On a given quantity of land, a yield increase that is due to factors other than variable inputs (e.g., inherent quality of land) can easily be viewed as a downward shifter in the marginal cost curve. Higher yields will increase the profits of the farmer and again increase his incentive to obtain rapidly the optimal position.

The final suggested influence is the elasticity of supply of inputs facing the farmer. As these elasticities go toward zero, the marginal cost curve becomes steeper, increasing the cost of being a given quantity of output away from the optimal (see figure 1). Starting in equilibrium at Q_1, the price changes so the new optimum is

Q^o. The loss due to immobility with inelastic supply is COA, while the loss associated with elastic supply is BOA. Note that the profit-loss coefficient is expressed in terms of an equal movement in quantity, not in the more intuitive equal movement in price. This leads to the uncomfortable, but correct, figure 1.

Equation (7) includes factors hypothesized to affect a_2:

$$a_2 = a_2[\epsilon_i, \sigma_{ij}, S, E], \tag{7}$$

where σ_{ij} is a vector of partial elasticities of substitution in the production function. Nerlove recognized the supply elasticity relationship and assumed that less than perfectly elastic supply was the dominant force in keeping the adjustment process from being instantaneous. The effects of the elasticity of substitution occur whenever ϵ_i is finite. The more flexibility in the production function, the "easier" will be the adjustment. In the limiting case, where $\sigma_{ij} = 0$ for all i and j, and $\epsilon_i = 0$ for any input, a_2 goes to infinity and the adjustment (g) goes to zero.

The scale parameter is more difficult to interpret. One can imagine economies of scale in changing over a large process, but there is a school of thought that suggests small firms are more flexible. Difficulties with imperfect capital markets may also play a role here. In other types of adjustment processes, Griliches (1957) and Huffman both found positive effects of scale, but here there is no a priori assumption as to the sign of the effect.

The important theoretical problem is how education works to reduce a_2. Several proposals have been made, in a general manner, as to how education eases adjustment. Schultz, among his several suggestions, lists schooling's contribution to improved perceptions of economic parameters. Lucas suggests there may be a learning period in which new capital units are used only at partial efficiency. Though not discussed explicitly in his study, it would be a logical step to include education as a variable that shortens this learning period and, hence, the rate of adjustment to equilibrium.

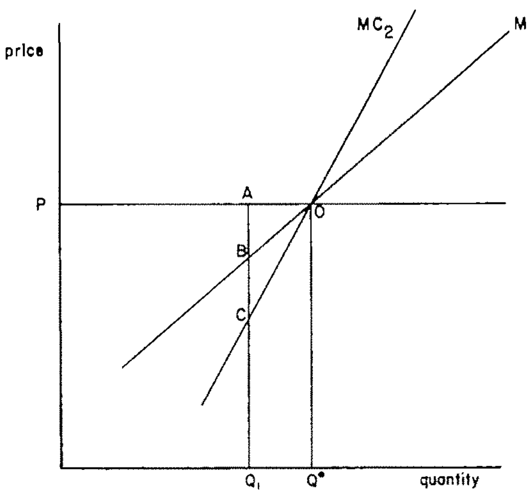

Figure 1.

Equation (4) assumes that all desired values, as well as the parameters a_1 and a_2, are known with certainty, and that the adjustment path commanded by g is optimal and not simply an artifact of imperfect information. A clue to the way education may contribute to lowering a_2 is found in Huffman. He showed that not only education but also extension activity acted as a contributor to adjustment. Additionally, he found that they were gross substitutes in shortening the lag to equilibrium. We know that a major role of the extension service is to distribute information about production techniques. This imperfect information could alter our quadratic loss function. Suppose that the available production function, as seen by the decision maker, is a set of past production points; then there is a constraint on the elasticity of substitution. Production will shift only along well defined paths of past combinations. If education or extension activity can broaden the area of feasible production points, then this must increase σ_{ij} to the value it assumes in the classical production function where information is perfect. Since the effect of σ_{ij} on a_2 is negative, and σ_{ij} and E move together, increases in E will lower a_2 and increase the rate of adjustment.

There is another route in which the education effect may contribute, and this is closely related to the "worker effect" of education. Suppose that schooling leads to a higher level of "effective labor units" per worker (ELU: an attempt to make the labor unit homogeneous). Given factor prices and constant returns to scale, optimality conditions would require a higher level of other inputs per individual as his education rises. Of course, these other inputs include land and, hence, we should predict that better educated farmers operate larger farms. Now, if the partial effect of scale on a_2 is negative, as Huffman's study would suggest, then we would again observe a negative contribution of E to a_2. There are now two possible ways in which education may hasten

adjustment toward equilibrium without having to resort to the vague notion of supply "shifters."

The total effect on g by the mentioned factors may be summarized. Increases in education, yield, and the elasticity of substitution all contribute to the hastening of adjustment. Size of farm may or may not also contribute. If there are economies of scale in production and adjustment, then g should unambiguously increase. An increase in the supply elasticities of inputs works to make adjustment easier (through lower a_2) but makes being away from the optimal less costly (lower a_1). The net effect is ambiguous.

Empirical Findings

In estimating supply equations in the form of equation (3), we first must account appropriately for the expected price variables (the own price of soybeans, and the cross prices of corn and cotton). Rather than resorting to ad hoc methods, this paper uses expected prices formed in the manner suggested by Muth. Rational expectations theoretically employ all economically feasible market information in forming future prices. A model of the relevant market is constructed, and the price predictions are extracted from the estimated model. The model we used to simulate the soybean market is given in the following equations:

$$Q_t^d = a + bP_t + cI_t, \tag{8}$$

$$Q_t^s = d + eP_t^e + fC_t + gG_t + y_t, \text{ and} \tag{9}$$

$$Q_t^s = Q_t^d, \tag{10}$$

where t is the subscript denoting time. Q^s and Q^d are quantities supplied and demanded, I is income, C is an index of factor costs, and G is a variable that captures government programs. Aggregate demand is viewed as deterministic and depends only on price and income. Aggregate supply is produced with a one-period lag and depends on expected price, costs of inputs, and government programs designed to influence the market. Supply is subject to a disturbance. The market clears each period.

Several assumptions were critical in the estimation of this model. First, only supply is stochastic. If both supply and demand are stochastic, it can be shown that no possible substitutions can be made to eliminate past unobservable disturbance terms from the equation to be estimated. Next, for simplicity, no cross-price terms were included. Several investigations using cross prices were made but the gains in prediction accuracy were so slight as to not justify the additional complexity.

Assuming the disturbance term, y_t, is a discrete linear process of current and lagged disturbances, one can solve for P_t in terms of observable current and past variables. This was done and then expectations were taken from the estimated regression equations. The expected and actual prices for soybeans are shown in figure 2. All monetary variables were deflated to give a measure of real movement through time, with the *numeraire* year being 1970.

An alternative procedure of using futures market prices as the predictor is suggested in Gardner. Tests were made using Gardner's method and the results were similar to those obtained above.

To capture variation in the rate of adjustment parameter, we desire the smallest observational unit possible. Data on acreage harvested by county is readily available for the postwar period from the state statistical reporting services. The sample here consists of 483 counties from nine major soybean growing states in the Corn Belt and the Mid-South. Preliminary estimation of a subsample of counties indicated that regressions performed on the natural logarithms of the data fit better than those applied to the raw data. The model is readily transformed into logs and none of the characteristics are lost.

The pitfalls of estimating equations with lagged endogenous variables are well

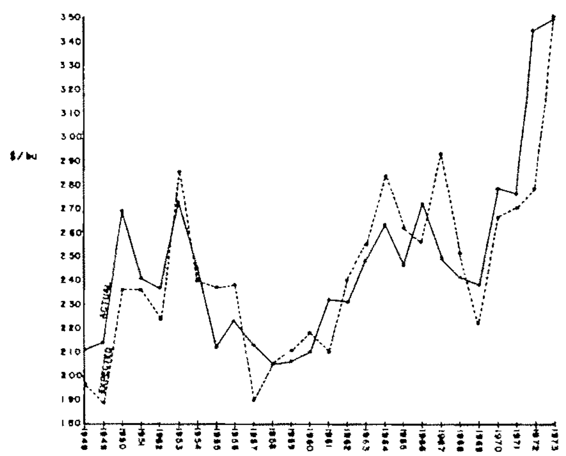

Figure 2. Actual and expected real soybean prices 1948–73.

documented in Griliches (1967). With any type of autoregressive structure of the disturbance, there will be correlation between the lagged endogenous variable and the disturbance term leading to inconsistent estimation of the coefficient on X_{t-1}. This coefficient is the source of our estimator of the rate of adjustment, and hence it is critical to remedy this problem. This technique takes equation (3) and estimates it in two steps. First we regress current acreage on current and lagged values of the exogenous variables. From this equation one gets a predicted value of acreage which is lagged and used as a proxy for X_{t-1} in the final regression equation. This procedure, by assumption and construction, eliminates any correlation between the error term and the lagged endogenous variable.

Regressions following the preceding method were run for all 483 counties, the goal being to find a broad cross-section of rates of adjustment. Two tests were employed to construct the final sample. First, the supply regression had to have an F-statistic significant at the 1% level. Second, the implied rate of adjustment had to be less than one. A g greater than one would imply continual over-adjustment (and violate the assumption that a_2 was positive).

Table 1 gives a summary of the findings for the rate of adjustment. The last column shows how many counties were rejected. The results were striking. The median of the distribution is .87 (mean = .78), which implies that the majority of the counties in the distribution moved extremely rapidly toward long-run equilibrium. The result, which conforms to our intuition about the farm situation appears to be the first of its kind in studies of supply. These findings are in sharp contrast to the studies of Houck, Ryan, and Subotnik and Kenyon and Evans, who, while using the same reduced form did not correct for the autoregression problem. Neither team was examining the problem of adjustment per se but their implied g's were much lower: .22 for the entire Corn Belt (Houck, Ryan, Subotnik) and .18 for the nation as a whole (Kenyon and Evans). This discrepancy is not due to different levels of aggregation. Preliminary supply functions for aggregated data were estimated in this study and they were found to have rapid adjustment as well.

Table 1. Summary of Rates of Adjustment by States

State	Number of Counties	Mean g	Standard Deviation	Counties Rejected
Arkansas	37	.615	.173	0
Illinois	72	.918	.110	9
Indiana	60	.836	.170	7
Iowa	88	.813	.168	2
Minnesota	24	.763	.205	0
Mississippi	47	.504	.196	0
Missouri	61	.747	.205	13
Ohio	37	.884	.067	3
Tennessee	22	.702	.221	0

It should be obvious that even during dramatic periods of change in the soybean market, adjustment seems to have proceeded rapidly in most cases. In terms of the model, this implies a dominance of a_1 over a_2; or simply put, the benefits of adjustment in any given period far outweighed the costs.

As high as the g's are, there are still significant differences across our sample; therefore the remainder of this paper is devoted to determining the source of these differences.

The data for the variables explaining the rate of adjustment was obtained from the U.S. *Census of Agriculture, 1964*. The yield variable is the mean of the 1964 and 1959 values reported. This should reduce some of the stochastic element that would exist in a single year measure of this variable. We recorded the data on size of farm two ways. First, we divided total acres by total farms to obtain the simple average size of farm. Then we divided total soybean acreage by the number of farms growing soybeans. This should be correlated with the first measure, but it may provide some insight into the soybean cultivation process. There was no available information on supply elasticities by region, so this variable is not included in any of the tests below.

The education of the decision maker was obtained through a weighting scheme proposed by Welch (1966). Data for school years completed by farm operators was given by groups in the 1964 *Census*. By taking the percentage of the population in each years-of-attendance group and multiplying by the appropriate weight and then summing over all groups, a measure of county education is obtained.

The basic problem with this type of measure is that it assumes the quality of education to be equal across counties. In an attempt to capture possible variation in the quality of schooling, we estimated a measure of expenditures per child on teacher salaries 1925–34 for each county. This decade captures the period when

most farm operators in the sample received at least some of their education. The hope is that variation across counties in this variable will proxie for the quality of that county's schooling.

In the theory above, no particular functional relationship is suggested between the rate of adjustment and the suggested explanatory variables. This would suggest that ordinary least squares (OLS) be applied to a variety of forms, but there are additional estimation problems. Recall that the g's are not known, but are estimated from the supply relationships. Saxonhouse discusses the problems surrounding estimated parameters as dependent variables in linear regressions. Basically, the difficulties lie in the fact that the standard errors of the g parameter are not the same across all of the counties. Testing for this heteroscedasticity, one may reject the null hypothesis that the variances are the same at the 95% confidence level. This leads to the use of generalized least squares, with the inverse of the standard deviations of the g's acting as the weights. The weighted least squares was done for a straight linear model with a variety of variable combinations. The results are in table 2.

The findings are in support of the suggested relationships. All the variables enter with the appropriate signs and usually enter at quite high levels of significance. It should be noted that no R^2 statistics are reported since this is a basically nonlinear procedure for which such a statistic is not appropriate. Also the significance levels are overstated somewhat since the estimated variances are used in the weighting scheme instead of the unobservable actual variances. Given the number of observations, however, this should not pose significant problems. Both size variables have a strong positive influence on the rate of adjustment except when placed in the regression together. This is a finding shared by both Griliches (1957) and Huffman. Yield enters positively and with a high level of significance. This is true of both measures of education. Table 3 gives the elasticities that result from the last equation in table 2.

The elasticities are generally low, which is in keeping with what one would expect. The median rate of adjustment is already .87, and its upper bound is 1.0. Approaching the maximum should not be easy. The elasticity of the years of education variable is not very informative in its present state simply because it is in the form of the Welch transformation. Translated back to years of schooling, it says that an increase of one year over the 1964 sample mean of ten years completed, would lead to an increase in g of .10. This is strong support for the hypothesis that education contributes to allocative efficiency. The finding that expenditures on schooling help to explain variation in g simply aids in the fine tuning of determining how schooling is translated into human capital.

Summary

Over the past several decades a dynamic theory of supply has emerged to explain movements in output through time. More re-

Table 2. Regressions on the Rate of Adjustment

	Independent Variables[a]					
Equation Number	Constant	Yield	Size #1	Size #2	Years of (Education)	Education Dollars (Ed&$)
1	−1.558	.010	.0012	—	.360	—
	(−5.13)	(5.58)	(6.39)		(14.53)	
2	−1.413	.0064	.0015	—	.334	.0028
	(−4.72)	(3.22)	(7.35)		(13.42)	(4.31)
3	−1.574	.0099	—	.00058	.330	—
	(−5.13)	(5.36)		(5.64)	(12.71)	
4	−1.475	.0080	—	.00058	.317	.0016
	(−4.79)	(5.35)		(5.64)	(12.05)	(2.48)
5	−1.424	.0064	.0014	.00005	.332	.0028
	(−4.72)	(3.22)	(4.57)	(.357)	(12.79)	(4.03)

Note: The t-statistics are in parentheses. Dependent variable in all equations is the rate of adjustment.
[a] Variables are Yield = average yield 1959, 1964; Size # 1 = soybean acres/soybean farms 1964; Size # 2 = average acres/farm 1964; Edyears = Welch measure county education 1964; and Ed$ = average expenditure per child per year 1925–34.

Table 3. Elasticities from Equation 5, Table 2

Independent Variable	Elasticity of g with Respect to Independent Variable
Yield	.19
Size #1	.10
Size #2	.01
Edyears	.70
Ed$	.13

Note: All elasticities calculated at the means of the variables.

cently a literature has emerged that examines the role played by education in adjusting to economic equilibria. This paper is a synthesis of these two areas of investigation. It begins by updating the application of the dynamics of supply. Techniques that have been discussed in the econometrics literature for many years, but, to this author's knowledge, have not been used in this type of analysis, were employed to produce consistent estimates of the rate of adjustment to long-run equilibrium. We found, contrary to other studies in the area, that the farm sector adjusts rapidly toward long-run equilibrium. It appears that American agriculture has not been overwhelmed by the dramatic changes in the soybean market over the postwar period.

It was argued that several economic variables, including education of the decision maker, played an important role in determining the rate of adjustment. This was set in the context of optimizing behavior and not in a world of haphazard disequilibria.

The results of the regression analysis performed with these variables strongly support the theory put forward. It was seen that both yield and scale were a positive influence to adjustment, reminiscent of the early adjustment studies on hybrid corn performed by Griliches (1957). Additionally, education of the decision maker made an impressive impact on the rate of adjustment, providing more empirical support for education's role in allocative efficiency.

The early theory of supply dynamics did not concern itself too much with the nature of disequilibrium adjustment. Its main concern was with the identification of behavior indicative of supply decisions whose impact spanned more than one decision period. Unfortunately too many years have passed without the discussion advancing greatly. This paper has been an attempt to revive this discussion, to suggest how the adjustment process may be influenced by economic forces.

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A "Putty-Clay" Approach to Aggregation of Production/Pollution Possibilities: An Application in Dairy Waste Control

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Utilizing the "putty-clay" production framework, a methodology for empirical assessment of the relationship between aggregate economic variables and environmental policy instruments is developed. Practicality is demonstrated by an application of the approach to the problem of dairy pollution in the Santa Ana River Basin of California. Results indicate pollution taxes to be substantially more efficient than emission standards in achieving a predetermined environmental quality goal. However, redistribution of tax revenues back to the regulated industry may be required to promote political feasibility.

Key words: aggregation, emission standard, environmental goal, manure, pollution tax, putty clay.

Interest in the state of the environment of the United States has been more prevalent during the last decade than perhaps at any other time in our national history. During this period, legislation at all levels of government has been enacted in an effort to improve or merely to maintain existing environmental quality. More recently, the economic literature has also given much attention to environmental issues. Originally, economists believed that pollution problems could be solved by using externality theory and a Pigouvian tax/subsidy (Mishan). However, this approach requires hard-to-get information about the social price of environmental quality, and those ideas have not been adopted in the process of practical policy formulation. Alternatively, Baumol and Oates suggested the adoption of a policy intended to minimize cost (as measured by industry profit foregone due to pollution abatement), given that pollution is constrained to a predetermined level. With fixed product price, this criterion is also equivalent to using the welfare measure suggested by classical surplus analysis (Just and Hueth). Pollution taxes, pollution licenses, and a mixed system using both have been shown to be relatively efficient tools for achieving this goal (Baumol and Oates, Montgomery, and Roberts and Spence, respectively). Nevertheless, policymakers have persisted in using emission standards to achieve environmental goals—an approach which seems inefficient in the context of these recent studies. Explanations for the preponderance of emission standards are policymakers' lack of understanding of alternatives (White) and their possibly well-founded fear of failing to achieve a pollution goal if taxes are used (Weitzman). That firms may be profitably using their political influence to obtain this kind of regulation has also been shown (Buchanan and Tullock).

The main purpose of this paper is to develop a methodology for calculating efficient pollution taxes, to demonstrate the practicality of its application, and to investigate quantitatively the superiority of taxes to standards in a particular problem of interest to agriculture—dairy pollution in the Santa Ana River Basin of California.

Dairy waste control has become a matter of concern in a number of areas in California due to the increasing salinity of water supplies to which dairy wastes are a major contributor. This problem is perhaps most serious in the Santa Ana River Basin of southern California

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where large capital-intensive dairies achieve impressive productivity levels but also generate levels of waste concentration which are particularly detrimental to the quality of groundwater. Thus far, water quality authorities in this region have adopted emission standards limiting the permissible disposal of wastes per acre of land. The type of emission standard formulated in this case is also commonly used in dealing with other agricultural environmental externalities throughout the state.

A problem common to both the pollution control policies recommended by economists and the emission standards being used in practice is that of estimating the relationship between policy parameters and the relevant aggregate variables (e.g., output, employment, and pollution). When dealing with a competitive industry in which firms have different production functions, this aggregation problem is not a simple one. Traditionally, it has been solved through the use of a representative firm whose response to pollution controls is used to estimate industry response. For example, Abrams and Barr and Horner use linear programming models to find the pollution tax schemes that achieve a given environmental quality goal at minimum cost. Ethridge (1972) has further exploited the assumption of identical parameters across firms in the context of neoclassical cost functions to investigate the differential in response to taxes and standards for a municipal waste treatment problem.

The approach in this paper, on the other hand, does not assume a representative firm but concentrates on the variability of production techniques and parameters across firms. With the production theoretic framework developed by Johansen, aggregate relations incorporating the response of individual firms can be derived for the short run. Our paper demonstrates how this procedure can be used for determining the short-run relations between environmental policy goals and instruments. This approach is, in fact, the basis upon which optimal taxes and standards are empirically developed.

Conceptual Framework

The "putty-clay" assumption plays a basic role in the production theoretic framework developed by Johansen and adopted in this paper. With this approach, it is assumed that capital goods (e.g., machinery) are specialized to the extent that their input-output ratio cannot be changed after installation. Therefore, prior to investment decisions, firms can choose among alternative technologies described by a neoclassical production function. But, once an investment takes place, the output capacity and the input-output relations for the firms are determined and cannot be changed in the short run. One thus observes various micro input-output coefficients which reflect past investment decisions taken by the various firms. Following this argument, Johansen investigated the case when the capacity distribution of input-output ratios is continuous, the price of all goods is given, and the firms are profit maximizers. By aggregating over firms for which production is profitable, Johansen found that aggregate input and output quantities can be expressed as well behaved functions of prices and the distributions of the input-output ratios. For example, a special case analyzed by Houthakker demonstrated that, if the input-output ratios are distributed according to the Pareto density function, then the aggregate production function is of a Cobb-Douglas form. Thus, the putty-clay approach justifies an aggregation procedure based on empirical estimation of the distribution of input-output coefficients. Given these distributions and prices, aggregate quantities such as output and pollution can be estimated as a function of policy controls.

In this paper an extension of the model to accommodate the effects of environmental policy imposed on an industry is employed. Two types of environmental policies are considered: (*a*) taxation of pollution and (*b*) regulation of the amount of emissions. A pollution tax has been shown to achieve any given pollution level at minimum cost, provided that the regulated firms seek to produce their output at least cost (Baumol and Oates). Although this paper is developed entirely in a static framework, the preferability of taxes to standards in a dynamic sense has been discussed in several recent papers (Wenders, Orr, and White).

In this case, the emission standards are considered on a per disposal unit basis. While no conceptual difficulty is encountered by an alternative definition of the standards (e.g., emissions per unit of output), this type of standard is popular in dealing with agricultural pollution problems as exemplified by the dairy pollution problem examined in this paper (where land serves as the disposal unit).

The short-run reaction of a firm to imposition of pollution taxes or standards will be within its production capacity and subject to its input-output ratios. However, a firm may acquire an additional disposal area at a cost (e.g., rental rate) which determines its relation between input devoted to pollution abatement and output.

The Model

Consider a competitive industry consisting of many firms which, in the process of producing a single good, generates a number of waste products that contain a single pollutant. The amount of waste generated is assumed to be an increasing function of output. It is also assumed that waste products can be transported out of the environmental impact region at a cost and that firms possess a quantifiable amount (possibly zero) of disposal area. In the more general case, firms may engage in a number of alternative pollution abatement activities. For example, increased by-product recovery and changes in input mix may typify a firm's response to pollution controls (see Ethridge 1973, for a more general discussion of this point). In the problem under consideration, various alternatives, such as recycling dairy wastes as animal feed and shifting to lower mineral content feeds, have been pursued. While these techniques may become important in the future, they unfortunately do not currently provide viable options and for this reason are not considered explicitly in the model. Thus, only removal of waste products and/or acquisition of more disposal area are assumed to be feasible abatement activities (aside from producing less output). In addition, it is assumed that the industry possesses the following characteristics: (*a*) the output capacity of each firm cannot be increased; (*b*) disposal area can be obtained to augment the existing amount; (*c*) production, because of short-run fixity of other capital assets, proceeds according to fixed coefficient production functions, with different coefficients across firms; and (*d*) the objective of each firm is to maximize profit.

A regional environmental regulatory agency is responsible for limiting pollution from the industry to a given level. It is also assumed that the agency is free to select either taxes or standards as the pollution control policy. The tax under consideration is a single unit tax on pollution, whereas the standards are restrictions on emissions per unit of disposal area. The objective of the agency is taken to be the achievement of the pollution goal at minimum cost as measured by industry profit foregone due to pollution abatement.

Under the above assumptions, firms will respond to standards by selecting the most profitable combination of output, disposal area, and waste removal that complies with the standards. If a tax is imposed, firms will engage in pollution abatement activities only as long as the marginal abatement cost is less than the tax rate. Firms will pay the tax on the remaining pollution.

Explicitly, consider the following notation for a typical firm: X_n, capacity utilization of firm n; Y_n, M vector of variable inputs used by firm n; H_n, K vector of the disposal area employed for each of the K waste products produced by firm n; W_n, K vector indicating the amount of each waste product transported from the region by firm n; $\bar{X}_n$, $\bar{Y}_n$, $\bar{H}_n$, $\bar{W}_n$, preregulation values of the respective variables; P, product price; P^Y, M vector of input prices; P^H, K vector of annual costs per unit of disposal area for each of the K waste products produced by firm n; P^W, K vector of removal costs for each waste product; G_n, K vector valued function of X_n where $G_n = (g_{n1}, \ldots, g_{nk})'$ indicates the amount of each waste product generated as a function of capacity utilization, $G'_n \geq 0$; A_n, scalar valued function of X_n, H_n, and W_n, where A_n indicates the pollution resulting from the operation of firm n; B, K vector of standards limiting the emissions of each waste product per unit of disposal area; and finally, t, tax per unit of pollution.

In this notation, the problem of firm n ($n = 1, 2, \ldots, N$) is to

$$(1) \quad \max Z_n = PX_n - P'^Y Y_n - P'^H H_n - P'^W W_n - tA_n,$$

subject to

$$(2) \quad G_n(X_n) - W_n \leq H'_n B,$$

$$(3) \quad X_n \leq \bar{X}_n,$$

$$(4) \quad H_n \geq \bar{H}_n,$$

$$(5) \quad Y_n \geq 0,$$

$$(6) \quad W_n \geq 0, \text{ and}$$

$$(7) \quad A_n(X_n, H_n, W_n) = A_n.$$

Two special cases of this model are of interest in the application discussed below: (*a*) a non-

zero value of t, with $\boldsymbol{B}$ very large, is a model of the firm where only a pollution tax is used; and (b) a zero value of t and a small $\boldsymbol{B}$ comprise the case of standards. In the latter case, the first K constraints in (2) limit the firm's emissions. If $\boldsymbol{B}$ is large, as in the tax case, these constraints are not binding. The constraint in (3) represents the condition that the firm's vintage technology and resources (which determine capacity) are fixed in the short run. The solution of the problem determines the firm's output (capacity utilization), level of input use, and pollution generated. These profit-maximizing choices, of course, depend on the policy parameter values being used.

It is assumed that firms earning negative quasi-rents (firms not even recovering variable costs) will cease production in the short run. Hence, only if the optimal solution, Z^*_n, is nonnegative will firm n continue to operate. Let the operating status be denoted by γ_n, where $\gamma_n = 1$ if $Z^*_n \geq 0$ and 0 otherwise. Then, the increase in costs associated with firm n due to pollution abatement for particular values of the parameters $\boldsymbol{B}$ and t is given by

$$C_n = (P\bar{X}_n - \boldsymbol{P}'^Y\bar{\boldsymbol{Y}}_n - \boldsymbol{P}'^H\bar{\boldsymbol{H}}_n - \boldsymbol{P}'^W\bar{\boldsymbol{W}}_n) - (Z^*_n + tA_n)\,\gamma_n;$$

and the pollution contributed by firm n is

$$A_n = A_n(X^*_n, \boldsymbol{H}^*_n, \boldsymbol{W}^*_n)\,\gamma_n,$$

where X^*_n, $\boldsymbol{H}^*_n$, and $\boldsymbol{W}^*_n$ are the profit-maximizing values of the respective variables. The term tA_n is included in firm cost because taxes are redistributed; only the pollution abatement cost (net of tax) is a loss to society.

Short-run aggregate cost and short-run aggregate pollution functions can thus be obtained for a wide range of parameter values by combining C_n and A_n. That is,

$$C\,(\boldsymbol{B}, t) = \sum_{n=1}^{N} C_n(\boldsymbol{B}, t) \tag{8}$$

gives the aggregate cost as a function of the policy controls; and

$$A\,(\boldsymbol{B}, t) = \sum_{n=1}^{N} A_n(\boldsymbol{B}, t) \tag{9}$$

gives aggregate pollution as a function of policy control.

Under assumptions similar to those in this paper, Hochman and Zilberman demonstrate continuity and differentiability of the aggregate relations in (8) and (9) provided that the underlying capacity utilization distribution of the industry is continuous and differentiable. If N (the number of firms) is large, the distribution of firm capacities may reasonably be approximated by a continuous function, thus enabling the aggregate cost and aggregate pollution functions to be considered as possessing these properties.

For application, the trade-off relationship between cost and pollution is of primary interest; this is, in effect, the trade off between economic efficiency and environmental quality. The slope and shape of the trade-off curve between cost and pollution under each policy can be inferred from the aggregate cost and aggregate pollution functions. In particular, if both are convex, as might be expected, the trade-off curve is negatively sloped and convex to the origin as shown in figure 1.[1] A series of points on this curve is found by using the model in (1) through (7) and aggregation procedures in (8) and (9) to determine the set of parameters corresponding to a particular pollution level, A_0, and then selecting the parameters of this set, say, $\boldsymbol{B}_0$ and t_0, for which cost C is minimized. Although tedious computations are required to develop these curves, it was found that, for the empirical case examined in this paper which dealt with an industry of more than 400 firms, the results were easily obtained using computer algorithms.

Application to the Santa Ana River Basin Dairy Industry

The dairy industry in the Santa Ana River Basin of California is the principal source of dairy products for the Los Angeles area. The operation of these dairies generates solid waste (manure) and liquid waste (washwater from washing the cows prior to milking). While the solid waste may be transported from the region, the liquid waste, which contains approximately 10% of the total manure produced, must be disposed of on the dairy since transport costs are prohibitively large and no

[1] A more rigorous and general development of these results is possible. For standards ($t = 0$), one can argue that $dC = \langle \nabla C(\boldsymbol{B}), d\boldsymbol{B}\rangle \leq 0$ and $dA = \langle \nabla A(\boldsymbol{B}), d\boldsymbol{B}\rangle \geq 0$ for $d\boldsymbol{B} \geq 0$ since $\nabla C(\boldsymbol{B}) \leq 0$ and $\nabla A(\boldsymbol{B}) \geq 0$. Thus, $dC/dA \leq 0$ for $d\boldsymbol{B} \geq 0$. Likewise, $d^2C = \langle d\boldsymbol{B}, [d^2C/d\boldsymbol{B}^2]\, d\boldsymbol{B}\rangle \geq 0$ and $d^2A = \langle d\boldsymbol{B}, [d^2A/d\boldsymbol{B}^2]\, d\boldsymbol{B}\rangle \geq 0$, since convexity implies $[d^2C/d\boldsymbol{B}^2]$ and $[d^2A/d\boldsymbol{B}^2]$ are positive nondefinite. Thus, $d^2C/dA^2 \geq 0$. For a tax ($\boldsymbol{B}$ large), on the other hand, one can argue that $dC = C'(t)\, dt \geq 0$ and $dA = A'(t)\, dt \leq 0$ for $dt \geq 0$ since $C'(t) \geq 0$ and $A'(t) \leq 0$. Thus, $dC/dA \leq 0$ for $dt \geq 0$. Likewise, $d^2 C = C''(t)\, dt^2 \geq 0$ and $d^2 A = A''(t)\, dt^2 \geq 0$, since convexity implies $C''(t), A''(t) \geq 0$.

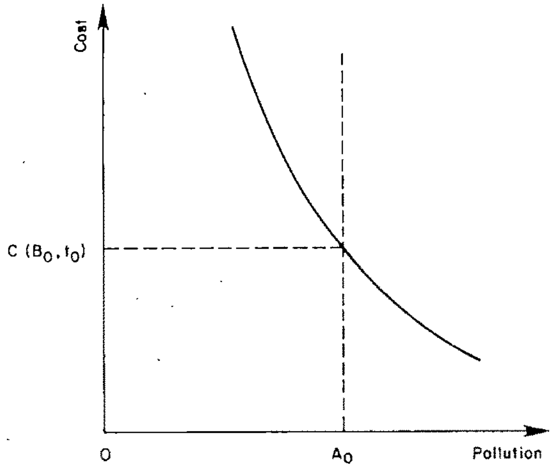

Figure 1. Cost and pollution trade-off curve

existing sewer system can handle the amount of water involved.

Because dairies in this area are typically quite large in terms of herd size and have high cow/land ratios, the volume of manure and dairy washwater produced presents serious disposal problems when compared to the relatively small amount of land (disposal area) which the typical firm possesses. A common situation is that of a 500-cow herd operated on 10 acres or less. Given that each cow produces approximately 2 tons of manure per year and requires 50 gallons of washwater per day (Webb), the disposal problem is apparent.[2] The salts (dissolved minerals) contained in the wastes generally reach groundwater by percolation, thus polluting the main regional water supply.

A study conducted by the regional water quality authorities has determined that the viability of the water supply can be maintained if the total annual salt contribution is limited to 3,600 tons in the basin. To reach this goal, waste disposal requirements have been established which limit the disposal of manure to 3 tons per acre per year. This single standard implicitly limits the disposal to 750 gallons of washwater per day (which results in 3 tons of manure per year) per acre or any equivalent combination of the two. In the previous notation, the standards are represented by $B_1 = 3$ and $B_2 = 750$.

[2] This paper is designed to demonstrate a useful methodology. Only the best information available (mainly from Webb) for many of the parameters in the model is used. Neither an extensive discussion of the underlying estimation procedures used elsewhere nor a sensitivity analysis with respect to the assumed values seems appropriate.

For this case, data for 418 firms ($N = 418$) regarding herd size (X_n) and disposal acreage (H_n) have been developed by the California Regional Water Quality Control Board. Data for the cost of transporting manure out of the region (P_1^w), the cost of transporting washwater (P_2^w), the annual cost of an additional acre of disposal land (P_1^H, P_2^H), and average profit per cow (π_n) are given by Smith and his colleagues: P_1^w = \$6.00 per ton, $P_1^H = P_2^H$ = \$583, P_2^w = prohibitive, and π_n = \$41. The function $G_n\ [g_1(X_n), g_2(X_n)] = G_n\ (1.8\ X_n, 50\ X_n)$ (manure [tons per year] and washwater [gallons per day] generated by X_n cows) and an emission-pollution relationship given in table 1 have been developed by Webb. Using this information, the model and aggregation procedure were employed to derive aggregate cost and pollution resulting from existing standards as well as the trade-off curves when various alternative standards and taxes are imposed as pollution control policies (figure 2). The apparent piecewise linearity in figure 2 is due to the piecewise linearity imposed by the table 1 relationship. Existing and optimum policy parameter values and the resulting values of the aggregate variables are given in table 2. Note that existing standards fail to achieve the pollution goal; however, the goal can be achieved through the use of the best standards indicated. By "best" standards is meant the values of standards which achieve a given pollution goal at a lower cost than any other possible standards. However, the superiority of taxes over even the best stan-

Table 1. Santa Ana Dairy Emission-Pollution Relationship

Emissions (Manure) per Acre	Salts Added to Water Supply
tons	
0	0
2	.23
4	.47
6	.68
8	.96
10	1.23
12	1.53
14	1.73
16	2.06
18	2.34
20	2.63
22	2.91
24	3.19
26	3.48
28	3.77
30	4.06

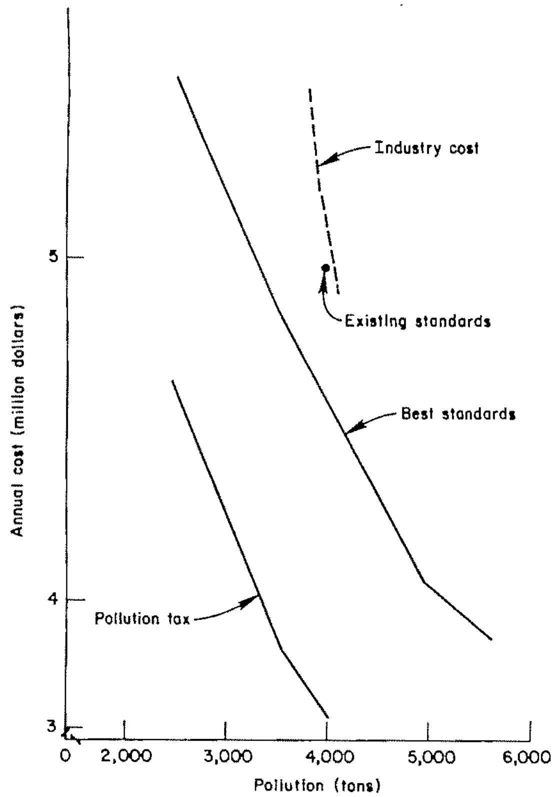

Figure 2. Cost and pollution trade-off curves

dards is evident since the tax trade-off curve is below that of standards at all pollution levels. In this case the tax yields a 21% savings in annual cost (approximately $1 million) over the best solution available under standards.

The efficient solution induced by employing a tax is due to the flexibility it provides individual firms relative to standards. Abatement costs may differ substantially among firms; yet, standards require firms with both high and low cleanup costs to reduce emissions to the same level. A tax, on the other hand, encourages cleanup where it is least costly, in low abatement cost firms. Firms for which emission reduction is expensive simply pay the tax and continue operating. From the standpoint of the industry as a whole, the total cost of pollution abatement is minimized when the marginal abatement cost is equal for all firms. The tax allows this adjustment to occur while standards do not.

Practical Applicability

Since a tax on pollution might in itself be difficult to administer (due to metering costs, for example), it is important to find ways to make tax controls applicable. To do this, note that, once the optimal tax on salt contribution to groundwater is known, it can be used in conjunction with table 1 (which indicates the relationship between tons of manure per acre and salt added to groundwater) to form table 3. The tax schedule in table 3 gives the tax per ton of manure disposed of on an acre corresponding to various emission levels. The exact tax rate for each dairy can be calculated using this table after computing dairy emissions per acre. Since, according to Webb (p. 83), dairy cows in the Santa Ana River Basin produce 2 tons of manure per cow per year, emissions per acre may be simply calculated by subtracting the amount of manure hauled from twice the herd size and then dividing by the amount of disposal acreage. This simple formula is obtained from the relation given by

$$\frac{g_{n1}(X_n) - W_{n1} + .004\ [g_n(X_2) - W_{n2}]}{H_{n1} + H_{n2}},$$

where the factor .004 is the number of days in a year multiplied by 1.09×10^{-5}, the manure content in tons of a gallon of washwater, suggested by Webb. This formula requires only easily obtainable information. The efficient pollution tax is thus approximately as operational as emission standards.

Table 2. Cost and Pollution Under Alternative Pollution Control Policies

	B_1 (tons/acre)	B_2 (gallons/acre)	t ($/ton)	Pollution (tons)	Annual Cost ($)
Existing standards	3[a]	750[a]	0	3,941	4,977,909
Best standards	2	800	0	3,600	4,879,848
Tax	[b]	[b]	567	3,600	3,846,293

[a] Implied.
[b] Indicates very large values for B_1 and B_2.

Table 3. Efficient Emission Tax Schedule

Emissions (Manure)/Acre (tons)	Tax/Ton/Acre ($)
0	0
2	65
4	67
6	64
8	68
10	70
12	72
14	70
16	73
18	74
20	75
22	75
24	75
26	76
28	76
30	77

One should note, however, that, while the pollution abatement cost is minimized by a pollution tax, the total cost to the industry is actually less under standards since the industry bears the expense of the tax (which is not counted as a cost in determining the efficient controls). The broken line in figure 2 represents the cost to the industry if the pollution tax is used (i.e., abatement cost plus the amount of the tax). The location of this curve above the trade-off curve for standards illustrates that the interests of the dairy industry as a whole are better served when standards rather than taxes are used. This result also suggests that the industry may be less resistant to a pollution control program based on emission standards. Results thus support the public choice approach to environmental policy advanced by Buchanan and Tullock. They, in fact, explain the wider use of standards by showing that firms will work politically to secure them over other forms of regulation. In order to offer incentive for firms to accept taxes, a system for redistributing tax revenues back to the industry in a manner that will not otherwise affect industry operation may thus be necessary from a political point of view.

Concluding Remarks

Though taxes have been recommended frequently by economists as a pollution control policy, the practicality of taxes has remained questionable. This paper demonstrates that a simple and efficient taxation scheme can be developed using the same data base required in the computation of uniform least-cost emission standards. As indicated in table 2, the superiority of taxes to standards is substantial.

This paper is intended merely as a demonstration of a useful approach in instituting a taxation scheme and, as such, suffers from several shortcomings. Perhaps the most restrictive nature of this analysis is that it relates only to the short-run aspects of the putty-clay approach. With additional research, however, the putty-clay approach can be generalized in a dynamic setting incorporating new technological innovations (Solow); and similar advantages should be forthcoming.

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Adult Equivalent Scales: An Alternative Approach

Rueben C. Buse and Larry E. Salathe

Adult equivalent scales were estimated for five food groups and total food consumed at home. The scales were specified as continuous functions of age and restrictions were placed on the scales so that they approximate the way an individual affects household food expenditures throughout his life. The scale function is easily incorporated into expenditure models, and statistical tests can be used to determine the importance of household composition in explaining household expenditure behavior. Children were found to consume less total food—beef, pork, and vegetables—than adults, while the middleaged spent less on fruit than the elderly.

Key words: adult equivalent scales, food expenditures, household size and composition, socioeconomic variables.

Economists have long been concerned with observing, quantifying, and predicting the economic behavior of households. The highly complex interrelationships among expenditures, income, family size and composition, occupation, race, education, and other socioeconomic variables have made the task difficult. The use of equivalent scales has appealed to the economist for both theoretical and applied reasons. Using one number to account for individuals of various types can simplify the measurement and testing of expenditure behavior.

The purpose of this paper is to present a procedure for specifying and estimating a set of expenditure adult equivalent scales. The procedure is offered as an alternative to the method devised by Sydenstricker and King, and later revised by Prais and Houthakker, and Price. There are many possible scales including nutritional, income, expenditure, consumption, and welfare (Brown and Deaton). Each is simply a device for specifying the needs or requirements of an individual of a particular age and sex as a percentage of a standard or base individual. Generally, the base is taken to be an adult male.

In the Sydenstricker-King, Prais-Houthakker, and Price models, expenditures per adult equivalent are expressed as a function of income per adult equivalent. The model is of the form,

$$(1) \qquad \frac{E}{\Sigma c_j n_j} = a\left(\frac{Y}{\Sigma d_j n_j}\right)^b,$$

where E is expenditure on a particular commodity per household, Y is income per household, n_j is the number of persons in a particular age-sex group per household, c_j is the adult equivalent scale for the particular commodity, d_j is the adult equivalent scale for income, a is the regression constant, and b is the income elasticity.

In this approach, a specific type of person is characterized by the set of weights (c_j) for each commodity, the set for the adult male being the unit vector. These weights are used to calculate the specific size of the household for each commodity; but the income of the household is divided by a measure using weights (d_j) which represent a general scale. Under the standard requirements of demand theory, the income or general scale can be shown to be a weighted average of the specific scales for that individual (Cramer, p. 165–67).

In the Prais-Houthakker and Price ap-

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proach, household members are grouped into various age-sex categories so that the specific scales are stepwise discrete. The scales for a particular individual are viewed as being constant over a period of years, taking on new values at age thresholds. This stepwise specification is unnecessarily restrictive. Changes in household expenditure patterns may be a function of the individual member's biological and psychological growth, which is a continuous process. Price's estimates of the specific scales for six food expenditure groups indicate these scales vary significantly between age-sex categories. Another problem with the empirical application of the Prais-Houthakker and Price model is that it does not include socioeconomic characteristics of households which may be important in explaining household expenditure variation.

The alternative model described below attempts to resolve some of these problems. The adult equivalent scales are a continuous function of age. In the statistical model, household expenditures are expressed as a function of the number of adult equivalents in the household, household income, and a set of socioeconomic characteristics. This formulation has been widely used when information on age and sex is not available. Muellbauer has shown that this formulation is also appropriate when household utility is expressed as a function of the amounts of each good consumed per adult equivalent.

As stated earlier, in theory, the income coefficient can be shown to be a weighted average of the corresponding specific coefficients. The weights are budget shares. In practice, both sets are neither necessary to a proper specification of the Engel functions nor obtainable from the observed expenditure data. According to Forsyth, the restrictions on the parameters of the Engel functions prevent estimating simultaneously specific and income scales. Our model follows Forsyth, who indicated that the researcher need not postulate separate income and specific scales if he is interested in parameters that measure the total effect of an additional household member on household expenditures (Forsyth, p. 384–85).

The Alternative Adult Equivalent Scale Specification

The alternative adult equivalent scale specification draws upon Friedman and Blokland and Somermeyer who suggest specifying the scales as continuous functions of age and sex of the household members. In employing this suggestion, certain restrictions are incorporated into the scale function. The restrictions are designed to make the function approximate the way a particular individual affects household expenditure throughout his life.

Conceptually, an adult equivalent scale can be written as

$$A_{ij} = S_i(a_j, s_j), \tag{2}$$

where A_{ij} is the scale value for commodity i for an individual j, of age a_j, and sex s_j. The scale is assumed to take the same value at age zero for males and females. After birth, the scale is allowed to be different for males and females. It may reach a local maximum (minimum) and then decline (increase) to some value at biological and psychological maturity (e.g., 20 years), remain constant until the climacteric years (e.g., 55 years), after which it begins to decline (increase) and finally becomes constant in old age (e.g., 75 years).

A major problem to be resolved if the hypothetical scale is to be parameterized involves the selection of a functional form consistent with available prior information. For the present analysis, two cubic functions were spliced together and actual age was rescaled to handle what would otherwise be a discontinuity between years twenty and fifty-five.

The following properties were hypothesized as desirable for the scale function (commodity subscript is suppressed):

I. $S(0, 1) = S(0, 2) = \epsilon,$

where $s_j = 1$ for males and $s_j = 2$ for females;

II. $\dfrac{\partial S(a_j, s_j)}{\partial a_j} \begin{cases} \text{exists for } a_j \geq 0 \\ \text{equals } 0 \text{ for } 20 \leq a_j \leq 55 \\ \text{and } a_j \geq 75; \end{cases}$

III. $\dfrac{\partial^2 S(a_j, s_j)}{\partial a_j 2} \begin{cases} \text{exists for } a_j \geq 0 \\ \text{equals } 0 \text{ for } 20 \leq a_j \leq 55 \\ \text{and } a_j \geq 75; \end{cases}$

IV. $S(20, 1) = 1;$
V. $S(20, 2) = \gamma;$
VI. $S(75, 1) = \mu;$
VII. $S(75, 2) = \nu.$

Property I indicates that male and female scales are equal at birth. The II through VII

properties specify that the function be "well behaved" in maturing and climacteric years, but constant during maturity and old age. For ages 0 to 20 and 55 to 75, a cubic function permits incorporating the above properties.

To illustrate the procedure, assume the scale function for males age 0 to 20 is

$$(3) \quad S(a_j, 1) = W_{01} + W_{11}a_j + W_{21}a_j^2 + W_{31}a_j^3.$$

For a male between 0 and 20 years properties I, II, and IV are relevant. The first sets W_{01} equal to ϵ. The second imposes continuity and implies that at age 20 equation (3) becomes

$$(4) \quad 0 = W_{11} + 40\ W_{21} + 1200\ W_{31}.$$

Property IV constrains (3) for a male at age 20 to be equal to 1:

$$(5) \quad 1 = \epsilon + 20\ W_{11} + 400\ W_{21} + 8000\ W_{31}.$$

Equations (4) and (5) contain four unknowns and can be solved for W_{21} and W_{31}.

$$(6) \quad W_{21} = -.1000\ W_{11} - .00750(\epsilon - 1), \text{ and}$$
$$(7) \quad W_{31} = .0025\ W_{11} + .00025(\epsilon - 1).$$

Substituting (6) and (7) into (3) and relabeling W_{11} as δ, the scale function for males 0 to 20 years of age is

$$(8) \quad S(a_j, 1) = \epsilon + \delta a_j - \{.1\delta + .0075(\epsilon - 1)\}a_j^2 + \{.0025\delta + .00025(\epsilon - 1)\}a_j^3.$$

An equivalency-derived expression for females 0 to 20 years of age is

$$(9) \quad S(a_j, 2) = \epsilon + \zeta a_j - \{.1\zeta + .0075(\epsilon - \gamma)\}a_j^2 + \{.0025\zeta + .00025(\epsilon - \gamma)\}a_j^3.$$

For the age interval 55 to 75, the scale is assumed to be a monotone function of age. At age 75 it takes on the value μ for males and ν for females. The monotonicity condition sets W_{11} equal to zero. Incorporating these conditions yields equation (10) for males age 55 to 75,

$$(10) \quad S(a_j, 1) = 1 - .0075(a_j - 55)^2(1 - \mu) + .00025(a_j - 55)^3(1 - \mu),$$

and for females,

$$(11) \quad S(a_j, 2) = \gamma - .0075(a_j - 55)^2(\gamma - \nu) + .00025(a_j - 55)^3(\gamma - \nu).$$

At this point, the scale function consists of four cubic segments: two for males, [equations (8) and (10)], and two for females, [equations (9) and (11)]. To resolve the discontinuity problem for ages 20 to 55 and over 75, actual age a_j was rescaled to a^*_j in the following manner:

$$(12) \quad \begin{aligned} a^* &= a \text{ if } a \le 20 \\ a^* &= 20 \text{ if } 20 \le a \le 55 \\ a^* &= a \text{ if } 55 \le a \le 75 \\ a^* &= 75 \text{ if } a \ge 75. \end{aligned}$$

Summing the four equations across all household members and combining like terms yields equation (13), the total number of adult equivalents in a household:

$$(13) \quad A = P + \gamma Q + \epsilon R + \delta S + \zeta T + \mu U + \nu V,$$

where P, Q, R, S, T, U, and V are the weighted sums of rescaled ages of the household's members defined according to the conditions shown in equation (12). Thus, given the age-sex composition of the household P, Q, R, S, T, U, and V can be computed, while γ, ϵ, δ, ζ, μ, and ν are scale parameters to be estimated.

Certain particular values or combinations of values of the adult equivalent scale parameters have special significance. For example, if the value of ϵ, μ, ν, and γ are all equal to 1 and $\delta = \zeta = 0$, equation (13) collapses to a household size specification. If $\mu = \nu$, $\delta = \zeta$, and $\gamma = 1$, sex of household members is unimportant in explaining household expenditure patterns. Furthermore, the sets of values can be grouped to produce testable hypotheses regarding age and sex of household members for food expenditure behavior.

The Data

Data from the 1955 and 1965 USDA household food consumption surveys were utilized. In both surveys, expenditures on food were recorded for a week each spring. The food expenditure variable in both surveys is the money value of food used at home. It included purchased food as well as food that was home-produced or received as gifts or payments for goods and services.

To facilitate comparisons with other published research, the scales were estimated for food groups similar to those used by Price. These food groups are total food,

grain products, vegetables, beef and pork, milk, and fruits. Milk includes fluid milk and milk products but excludes butter. Unlike Price, our vegetables group includes dry beans, peas, and lentils. The other groups are identical to Price's groupings and are self-explanatory.

The 1965 USDA *Household Food Consumption Survey* reported actual age and sex of every person in the household, while the 1955 survey reported age-sex categories for household members. Since the actual age and sex of all household members is needed to compute P, Q, R, S, T, U, and V in (13) each household member was assigned an age and sex based on the age-sex category recorded for that member in the 1955 survey.

The Statistical Model

Parameters of the scale function are estimated by including in the household expenditure equation, i.e.,

$$E_i = E_i(Y, A_i, T_i), \tag{14}$$

where E_i is household weekly expenditure on the (ith) commodity, Y is household weekly income, A_i is the number of adult equivalents in the household, and T_i is a proxy subsequently assumed to measure household tastes and preferences. The 1955 and 1965 USDA household food consumption surveys provided data on some socioeconomic variables which can be used for T_i. These include region and urbanization and the race, education, and employment status of the household's female head.

Price differences were assumed to exist between geographical locations. Since food expenditures are expected to increase with household size, the larger the household the more it will be affected by increases in the price of food. For example, the dollar increase in food expenditures resulting from a 10% increase in food prices will be greater for a four-person household than for a single-person household. As a result, interactions between the number of adult equivalents in the household with region (BA) and with urbanization (GA) were entered as independent variables in the regression model.

Specifications for the female head's race, education, and employment status in the Engel functions were considerably more difficult to rationalize. For example, do these socioeconomic variables shift the slope or intercept of the Engel function? Employing linear regression and a subsequent analysis of the regression residuals via the University of Michigan's Automatic Interaction Detector (Sonquist, Baker, Morgan) suggested that the marginal propensity to spend on the six food groups varied by race (CY), education (DY), and employment status (FY) of the household's female head. Race of the female head also was found to interact with household size (CA). The addition of education (D) and employment status (F) of the household's female head as intercept shifters provided equations which had a lower standard error and with coefficients that more often a priori expectations.

Because the 1955 and 1965 USDA household food consumption surveys do not include the money value of each food item consumed away from the home, it was necessary to include a variable reflecting the number of meals eaten outside the home to adjust for different levels of home consumption. The variable (M) was defined as the percentage of meals eaten at home (i.e., number of meals eaten at home divided by twenty-one times household size).

A linear relationship was hypothesized between a household's expenditure on each food category and the interaction variables, income of the household (Y), the number of adult equivalents in the household (A), and the percentage of meals eaten at home (M). If the effect of adult equivalents is linear, it presumes that a change in food expenditure due to a change in household size is independent of the size of the household. However, Price's results suggest that the impact of an additional member on food expenditures decreases with an increase in household size. Therefore, the square of the number of adult equivalents (A^2) and its interactions with region (GA^2), urbanization (BA^2), and race (CA^2) were included as additional explanatory variables in the Engel functions. Thus, the function to be estimated is of the form,

$$E_i = E_i(D, F, Y, CY, DY, FY, A_i, GA_i, CA_i, BA_i, A_i^2, GA_i^2, CA_i^2, BA_i^2, M). \tag{15}$$

Including the number of adult equivalents squared and the associated interaction terms as explanatory variables prohibits the use of ordinary or generalized least squares, because the estimates for the parameters of the

adult equivalent scale function must be constrained to be equal for A_i, and A_i^2. A nonlinear regression algorithm using Marquardt's Compromise was employed to estimate the household food expenditure equations (Draper and Smith, p. 272–73).

The Results

In general, the results support the hypothesis that household size and composition are important in explaining variations in household food expenditures. The inclusion of additional socioeconomic variables to reflect heterogeneous tastes were also useful in explaining expenditure variations. The estimated interaction parameters between the socioeconomic variables and income and the number of adult equivalents suggest that the marginal propensity to spend on food declines with increasing education of the female head and employment of the female head outside the home. Holding all other variables constant, households residing in the South spent the least per adult equivalent, while households residing in the Northeast spent the most per adult equivalent on food. In addition, rural nonfarm residents spent less per adult equivalent on food than rural farm or urban residents. These relationships were consistent across nearly all of the food expenditure groups for both 1955 and 1965.

The coefficients of A_i (number of adult equivalents), income and M (the percentage of meals eaten at home) were at least twice their standard errors for every food group. The coefficients of the number of adult equivalents squared (A_i^2) were negative and at least twice their standard error for every food group except in the 1955 equations for vegetables and grain products.

Statistical tests were conducted on the adult equivalent scale parameters presented in table 1 (see Chow and Fisher). Results are presented in table 2. These tests indicate that sex and age of household members is statistically significant in explaining household food expenditure behavior. A test of the null hypothesis that sex and age is not important (household size specification) was rejected for every household food expenditure except fruits in 1955 (test 1).

The 1955 Adult Equivalent Scales

The scale intercept term, ϵ_i, measures the increase in the number of adult equivalents in a given household due to the addition of a newborn baby. γ_i, μ_i, and ν_i measure the increase in the number of adult equivalents to a household due to the addition of an adult female (age 20–55), elderly male (age $\geq$ 75), and elderly female (age $\geq$ 75), respectively. ϵ_i, γ_i, μ_i, and ν_i can also be interpreted as the change in expenditure i resulting from the addition of a newborn infant, adult female, elderly male, and elderly female, respectively, in comparison with the change in expenditure i resulting from the addition of an adult male to a given household. This can be shown by taking the partial derivatives of E_i in (15) with respect to R, Q, U, and V and dividing those partial derivatives by the partial derivatives of E_i with respect to P.

As expected γ_i, ϵ_i, μ_i, and ν_i were positive for every food expenditure category. γ_i and μ_i are statistically significant in every food expenditure equation while ϵ_i was significant in every equation except beef and pork, and ν_i was not significant in the vegetables equation. δ_i and ζ_i were not significant in the vegetables, beef and pork, milk, or fruits expenditure equations suggesting that for these food expenditures the scale function could have been specified as a strict monotonic function of age from youth to maturity.

The scale intercepts, ϵ_i were below 1.00 and also below the corresponding adult female scale value in every food expenditure equation except milk. For fruits, a newborn child's impact was not significantly different from that of an adult male or female.

The adult equivalent scale for grain products varied dramatically with a child's age. For example, a newborn child increased the number of adult equivalents by 23% of an adult male in 1955, but by the age of 8, the number of adult equivalents increased to 104% of an adult male. This indicates that a household containing children will spend a higher proportion of their food budget on grain products than a household that does not contain children. Further it indicates that preteenage children increase expenditures for grain products more than any other age group. The γ-values for total food, beef and

Table 1. Estimated Adult Equivalent Scale Parameters, 1955 and 1965 USDA Household Food Consumption Surveys

	Total Food		Vegetables		Grain Products		Beef and Pork		Milk		Fruits	
Parameter	1955	1965	1955	1965	1955	1965	1955	1965	1955	1965	1955	1965
γ_i	.8100*[a]	.7667*	.8903*	.9903*	.8293*	.7099*	.7282*	.6623*	.6118*	.7081*	1.0744*	1.2512*
	(.082)[b]	(.044)	(.175)	(.075)	(.103)	(.059)	(.128)	(.061)	(.095)	(.069)	(.288)	(.156)
ϵ_i	.2982*	.4470*	.4542*	.4770*	.2315*	.0265	.0112	.3042*	.6261*	1.0488*	.7589*	1.2028*
	(.086)	(.068)	(.178)	(.105)	(.109)	(.097)	(.130)	(.100)	(.118)	(.130)	(.300)	(.214)
μ_i	.6425*	.7819*	.6482*	.8559*	.7506*	.7789*	.5094*	.8395*	.8372*	.7014*	1.0435*	1.5376*
	(.089)	(.069)	(.207)	(.104)	(.134)	(.097)	(.135)	(.109)	(.115)	(.098)	(.287)	(.218)
ν_i	.4729*	.4939*	.2055*	.5583*	.6078*	.6109*	.3580*	.2607*	.5460*	.6485*	.9803*	1.2007*
	(.096)	(.056)	(.220)	(.084)	(.138)	(.080)	(.149)	(.088)	(.119)	(.083)	(.315)	(.173)
δ_i	.0895*	.0101	.0826	−.0107	.1865*	.3263*	.0906	−.0711	.0790	.0012	.1482	−.1036
	(.036)	(.023)	(.074)	(.035)	(.050)	(.040)	(.056)	(.032)	(.047)	(.042)	(.125)	(.066)
ζ_i	.0635	.0152	.0314	.0056	.2120*	.2893*	.0338	−.0348	.1070	−0114	−.0176	−.1811*
	(.044)	(.023)	(.090)	(.036)	(.056)	(.036)	(.067)	(.033)	(.058)	(.042)	(.147)	(.068)
R^2	.53	.59	.24	.40	.41	.50	.29	.34	.41	.44	.25	.28

[a] * Indicates coefficient was significant at the .01% level.
[b] Estimated standard errors in parentheses.

Table 2. Results of Statistical Tests Performed on the AES Parameters Derived from the 1955 and 1965 USDA Household Food Consumption Survey

Test		Food Groupings in which Test Was Rejected[a] 1955	1965
1	Age and sex not important	TF, V, GP, BP, M	TF, V, GP, BP, M, F
2	Sex not important	TF, BP, M	TF, GP, BP, M
2a	Sex of adults not important	TF, BP, M	TF, GP, BP, M
2b	Sex of elderly not important		TF, V, GP, BP, M, F
3	Age of males not important	TF, V, GP, BP, M	TF, V, GP, BP, M, F
3a	Male children not different from adult males	TF, V, GP, BP, M	TF, V, GP, BP
3b	Elderly males not different from adult males	TF, BP	TF, GP, M, F
4	Age of females not important	TF, V, GP, BP	TF, V, GP, BP, M
4a	Female children not different from adult females	TF, GP, BP	TF, V, GP, BP, M, F
4b	Elderly females not different from adult females	TF, V, BP	TF, V, BP

Note: TF is total food; V is vegetables; GP is grain products; BP is beef and pork; M is milk; F is fruits.
[a] Test was significant at the 95% level of confidence.

pork, and milk were significantly different from 1.00 (table 2, test 2a). These results indicate the impact of an adult female on household expenditures for total food, beef and pork, and milk is significantly less than that of an adult male.

The elderly male and female scales also follow expectations. The statistical tests indicate elderly males increase household expenditures less on total food, and beef and pork than adult males, and that elderly females increase household expenditures less on total food, vegetables, and beef and pork than adult females.

In summary, the 1955 adult equivalent scales estimated for the six household food categories exhibit many of the same age and sex differences uncovered by Price.[1] Price concludes: "Important differences exist among the various commodities. Relative to adults, children are high consumers of milk and grain products but very low consumers of beef and pork. Total food expenditures for the males were generally higher than for females, with the exception of fruit. The scales generally showed females to be low consumers of those foods thought to be high in calories, such as milk and grain products. Retired couples generally spend less on food than the adults still in the working force, with the exception of fruit. Like females, they seem to have a higher relative preference for the low calorie foods" (p. 233).

[1] The adult equivalent scales estimated in this study and those obtained by Price using the 1955 USDA household food consumption survey are not directly comparable. Price uses the average of the first male and female as the unit of comparison in deriving his scales and only the specific scales are estimated. It is interesting to note, however, that the two approaches do yield some of the same conclusions.

The 1965 Adult Equivalent Scales

The standard errors were moderately lower for the 1965 compared to the 1955 adult equivalent scale parameters probably reflecting the difference in the quality of data on age and sex of household members between the two surveys. Comparing columns in table 2 suggests that the lower standard errors in the 1965 results produce a larger number of rejections of the null hypothesis.

The scale intercept values, ϵ, ranged from approximately zero for grain products to 1.20 for fruits. The 1965 adult equivalent scales suggest a male child has less of an impact on expenditures for total food, vegetables, and beef and pork, but a greater impact on grain products than an adult male. In contrast, a female child adds less to household expenditures for total food, vegetables, fruits, and beef and pork, but adds more for grain products and milk than an adult female.

The difference in scale values for adult males and females indicates that females have less effect on expenditures for beef and pork, grain products, milk, and for total food

than their male counterparts. The sex of household members was not significant in explaining differences in household expenditures for fruits and vegetables.

The statistical tests indicate that elderly males increase household expenditures less for total food, grain products, and milk and more on fruits than their younger male counterparts. Similar tests on the elderly female scale parameter indicate their impact on expenditures for total food, vegetables, and beef and pork are smaller than for adult females. The elderly female scale values for milk, grain products, and fruits were also lower but the differences were not statistically significant.

Comparison of the 1955 and 1965 Scales

It is quite difficult to compare the large number of parameters generated by the analysis and the results of the subsequent statistical tests. Differences in data quality and the large number of observations increase the costs of trying to pinpoint the precise reason for observed differences in specific coefficients. It has been impossible to estimate how much of the observed differences in parameters are due to the relatively lower quality of the 1955 data set. Generally, however, the results conform to expectations or hypotheses can be advanced to explain observed differences.

Figures 1a–1f give the general impression that the 1965 estimates are larger than their 1955 counterparts but that most are not significantly different. Fruits show the largest differences, grain products the smallest. Contrary trends are observed in milk and grain products for elderly males and newborn children. The elderly male parameter for milk decreased between 1955 and 1965. This undoubtedly reflects the association of dairy product consumption with cardiovascular problems.

Except for grain products, the 1965 scale values for an infant were higher than those from the 1955 survey. The increased expenditures generated by an infant probably reflect the movement toward expenditures on larger amounts of more highly prepared baby foods.

For an adult female, the 1965 grain product scale value was slightly lower than its 1955 counterpart. The difference in the estimated adult female scale can probably be attributed to an increase in weight consciousness between 1955 and 1965. In response, females have tended to shift away from relatively high calorie foods contained in the grain products subgroup to the relatively low calorie foods included in the fruits subgroup.

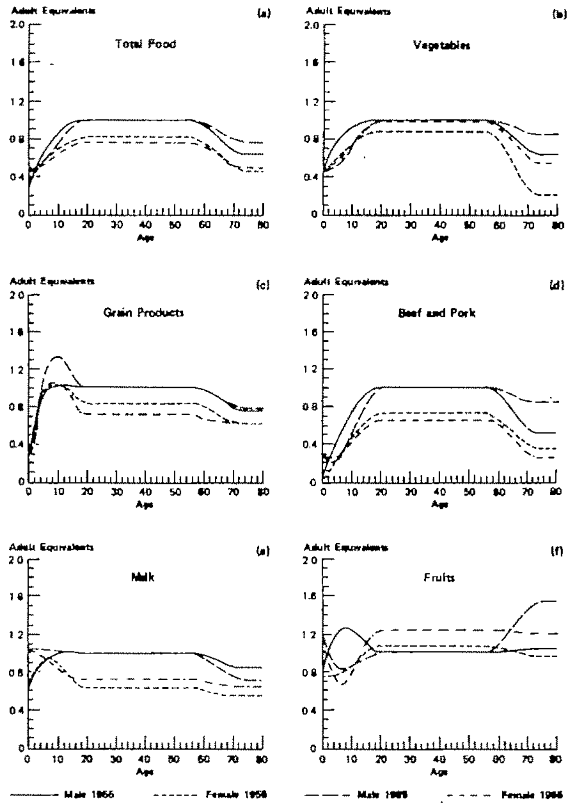

Figure 1. Plots of estimated adult equivalent scales for six food commodity groupings for 1955 and 1965

For milk, the estimated ϵ-value was significantly higher in 1965 than in 1955 (.63 compared to 1.05). The 1965 milk scale function remained nearly constant throughout youth for a male child, but declined throughout for a female child to the adult female value of .71 (figure 1e). For fruits, the 1965 scales are larger than those estimated from the 1955 data set. The increase in the availability of fresh fruits plus the increase in weight consciousness are possible explanations of the higher 1965 scale values.

Summary

This paper has demonstrated an alternative procedure for specifying and estimating adult

equivalent scales. The major advantages of the procedure over previous methods are that the scales are continuous functions of age, and the impact of a household member on household expenditures are measured under *ceteris paribus* conditions. Data from the 1955 and 1965 USDA household food consumption surveys were used to estimate adult equivalent scales for six food groups. Generally the scales conform to prior expectations. For example, adult females consume less total food, beef and pork, grain products, and milk, and consume about the same amount of vegetables and fruits as adult males, and with the exception of fruits, elderly persons spent less on food than adults aged 20–55. Children were found to consume less total food, vegetables, beef and pork, but more grain products than adults.

The method also provided for tests of other important socioeconomic variables. Holding household size and composition constant, the marginal propensity to spend for food declined with the education of the female head and when the female head worked outside the home. *Ceteris paribus,* households residing in the South spent the least per adult equivalent, while households residing in the Northeast spent the most per adult equivalent on food. Rural nonfarm residents spent less per adult equivalent on food than rural farm or urban residents.

There are two areas in which further research is required. First, better methods of finding and testing the strength of interactions between income, household size and composition, and the household's socioeconomic characteristics are needed. Second, the adult equivalent scales were estimated without maintaining a consistent income scale. Even though this formulation has been advocated by some economists, more research is required regarding the theoretical and statistical properties of the adult equivalent scale parameter estimates generated from these models.

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Optimal Pesticide Application for Controlling the Boll Weevil on Cotton

H. Talpaz, G. L. Curry, P. J. Sharpe, D. W. DeMichele, and R. E. Frisbie

A simulation model of interaction between the boll weevil insect subsystem and the cotton plant subsystem is presented. Field experiments provide the basis for validation of the model. Pesticide control scheme is introduced, and optimal control is achieved by using a numerical nonlinear dynamic optimization technique. Results of sensitivity analysis with respect to price changes are provided. Optimal policy for a single producer calls for three applications. Timing is robust, but dosage levels are sensitive to price changes.

Key words: boll weevil-cotton simulation, nonlinear optimization, optimal pesticide control.

The rise of energy and pesticide costs for agricultural use, combined with growing ecological and social concerns about pesticides, have recently attracted attention in economic literature. While biologists have concentrated on understanding the interaction between plant and pests with or without pesticide control, many economists have focused their attention on the economics of pest control. Headley gave an economic interpretation to the entomological term "economic threshold"; further refinements and extensions were offered by Hall and Norgaard, and Talpaz and Borosh. Optimal pesticide applications on insects in silo was developed by Shoemaker (1973a,b). The economic problem of pest resistance was dealt with by Hueth and Regev, and Taylor and Headley. A significant development was made by Regev, Gutierrez, and Feder in optimizing an economic objective function subject to a biological plant-pest system. However, they were forced to compromise by simplifying the system when it came to obtaining a solution because of limitation of the solving algorithm. For the same reason, this solution was further simplified by considering a steady-state solution which avoids the complexity of a truly dynamic system (Regev, Gutierrez, Feder, p. 191). Another way of avoiding complexities was the empirical approach taken by Talpaz and Frisbie.

The objective of this paper is to describe an economic optimization model incorporating a detailed plant-pest interactive system with a pesticide control scheme, keeping all the complexities intact under dynamic conditions. This study is concerned with the optimal policy of a single decision maker, where these policies are not concerned with externalities. Effective insecticides are assumed and used in addition to natural mortality factors.

The first section of this paper describes the biological system as an interaction between the cotton plant and boll weevil subsystems operating under certain approximate realistic environment. The following section relates pesticide applications to insect mortality, and describes and defines economic measurements. The optimization process is discussed briefly, and a demonstration is presented which includes some sensitivity analyses and related discussion.

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Boll Weevil-Cotton Model

The boll weevil is a key pest of cotton. Predators are of limited consequence under most systems. The parasite *Bracon mellitor* does cause some minor mortality to first generation weevils (Barfield, Bottrell, Smith). The major crop damage is caused by the female adults who lay single eggs in the cotton flower buds (squares) or less frequently in the small bolls (these structures are hereinafter called fruit).[1]

The adult weevils are mobile but actually migrate into and out of the cotton field only during early or late season. Thus, the field populations are almost totally determined by the early season immigration and subsequent in-field growth. The adult female is capable of laying 250–300 eggs during her life; the quantity is a function of temperature as depicted in figure 1. Food availability is a major factor in reproduction. The male adult feeds on squares and bolls, infrequently changing feeding sites. Hence, the female egg-laying process contributes the major portion of the damage to the crop.

The immature weevil develops completely within the attacked fruit and emerges as an adult generally from two to three weeks later. This immature developmental emergence time is a strong function of temperature, as shown in figure 2. The emergence of a cohort exhibits a wide, but consistent, variability about the mean developmental time (figure 3). (See Sharpe et al. for a detailed discussion of stochastic boll weevil emergence.) The infested cotton squares are generally abscised by the plant and fall to the ground from three to seven days (averaging approximately four days) after attack. Once the fruit are abscised from the plant, they begin to dry out. Depending on the microclimate of the square, the square can dry out before the immature weevil reaches a critical size for survival. Thus, immature weevil survival becomes a race between the microclimate-controlled processes of development and square drying (DeMichele et al.). Immature weevil mortality as a function of temperature and relative humidity is depicted in figure 4. One of the most important aspects of immature survival is the distribution of fruit sizes on the cotton plants within the weevil preference range (approximately 7/32″ to 13/32″ diameter fruit).

Because immature boll weevil survival is directly related to fruit drying, the size distribution of available fruit on the cotton plant is of critical importance in modeling the system. This size distribution can change drastically over a period of two to three weeks (Walker). In addition, the cotton plant has a high compensation capability for replenishing lost fruit. Approximately 50% of the squares

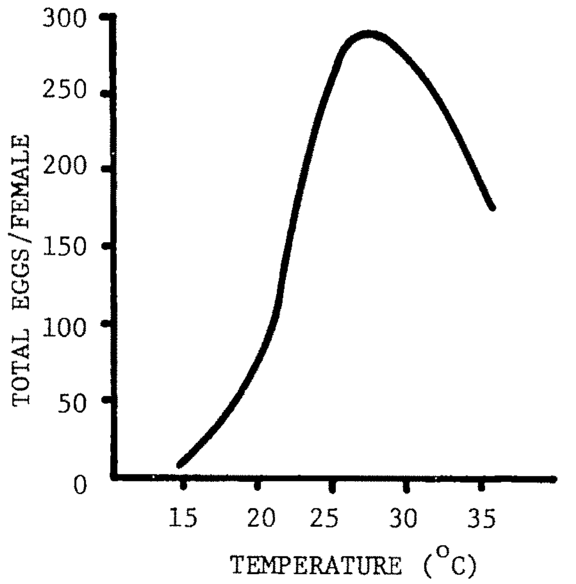

Figure 1. Total number of eggs per female as a function of temperature. Source: Developed from experimental data of Isley.

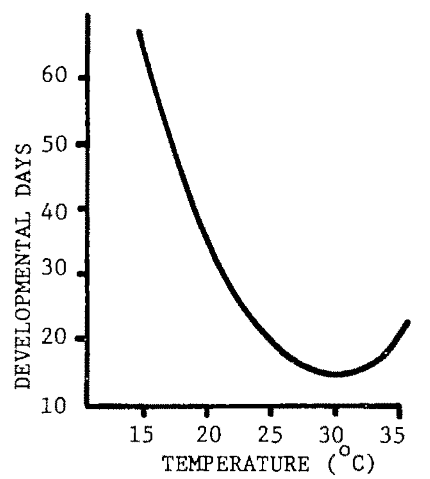

Figure 2. Boll weevil immature developmental time as a function of temperature. Source: From the model of Sharpe et al.

[1] Documentation for the model is being prepared and will be available upon request from G. L. Curry, Industrial Engineering Department, Texas A&M University, College Station, Texas 77843.

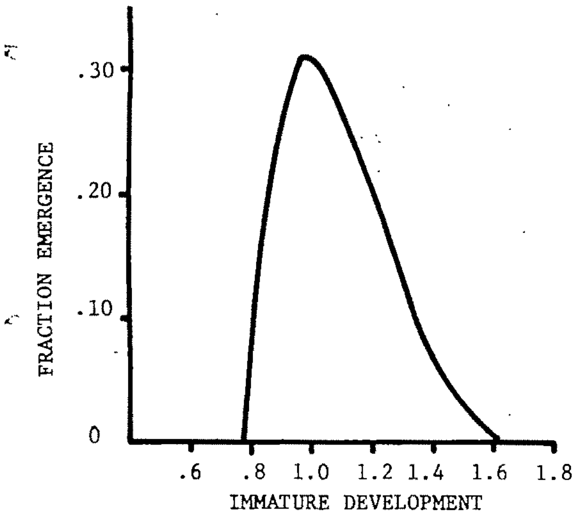

Figure 3. Immature emergence distribution on developmental scale. Source: Sharpe et al.

and 10% of the bolls are normally shed due to natural (nonpest-related) causes. Thus, the plant-weevil interaction has a strong effect on weevil populations and, hence, on ultimate crop yields.

In addition to the boll weevil model, a

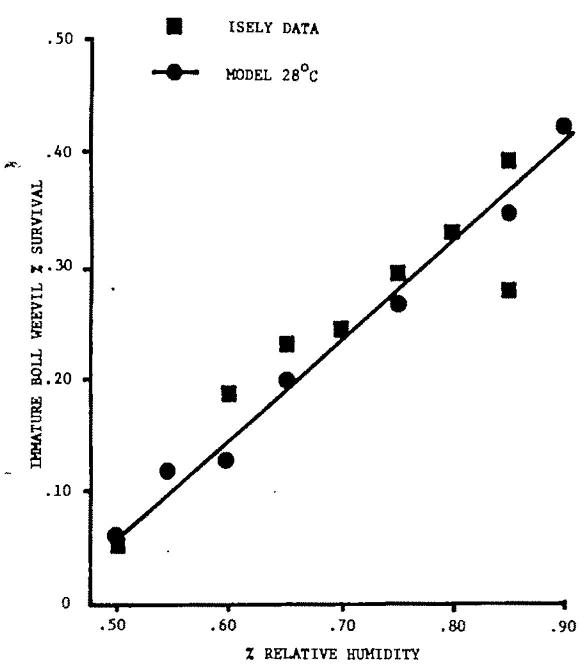

Figure 4. Comparison of Isely and model results for immature boll weevil survival as a function of relative humidity at 28° centigrade, based on an average square distribution for dates 7-20, 7-23, 7-25 at Waco, Texas, 1973. Source: Curry et al.

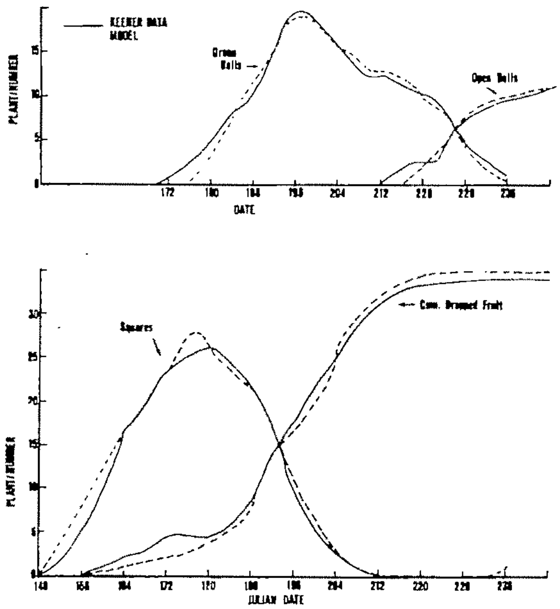

Figure 5. Keener's experimental data and model results for TAMCOT SP37, 40″ rows for College Station, Texas, 1974.

model of the cotton plant fruiting characteristics which yields the dynamic fruit size distributions over time has been developed (Curry, Keener, DeMichele). The model is temperature dependent and describes central Texas cotton fairly well (figure 5).

Component Interactions

The composite model of the boll weevil-cotton crop system consists of a temperature dependent boll weevil population model (for details, see Curry, Feldman, Smith), a mechanistic fruit-drying model for immature weevil survival, and a cotton fruiting model. The composite model incorporates three independent developmental time scales: (*a*) weevil development, (*b*) square drying, and (*c*) cotton plant development. These developmental parameters are computed from hourly temperatures and accumulated for population count updates which occur at four-day time intervals.

The dynamics of the plant regrowth characteristics depend on the fruit structure (i.e., population and location) on the plant. Plants which were attacked four days ago would have a different structure than those attacked eight days ago because of their associated regrowth time. To allow for these nonlinear regrowth characteristics, the model

segments the field population into a maximum of eleven categories of plants. The weevil in the model attacks a field plant that is the weighted average of the various plant categories. The separation of the crop into various categories allows the delineation between natural abscision and weevil-incurred damage.

When plants are attacked on a given day, the average fruit size distribution for the attacked plants is associated with the egg cohort laid that day. This distribution and subsequent climatic conditions determine the survival proportions for each specific egg cohort. In actuality, the weevil egg-laying preference, based on the available fruit size distribution, determines the attacked fruit distribution. The model of Jones et al. is used to incorporate these preference aspects into the model.

Finally, the proportion of crop canopy closure throughout the season determines the probability that a fallen infested fruit will be exposed to direct sunlight. Fully exposed ground temperatures can range up to 140° fahrenheit, much beyond the lethal range for weevil immatures (Fye and Bonham). The model incorporates multiple immature weevil and different fruit drying environments (for analytical treatment of light penetration of cotton crop canopies see Mann et al. 1975, 1977).

All of the above model components have been computerized to simulate the cotton-boll weevil behavior. Figure 5 shows the model results compared with data gathered and discussed by Curry, Keener, and DeMichele.

Pesticide Kill Function

Theoretical studies of the dosage-response function yield a sigmoid-shaped curve (e.g., Finney). This is based on the argument that the pest tolerance to variable pesticide dosage is a random variable with nonsymmetric distribution skewed to the right. Following Talpaz and Borosh, a cumulative Weibull distribution function has been used to represent the proportion of killed pests of the existing population given by

$$(1)\quad K(x) = \begin{cases} 1 - \exp(-\beta x)^{\alpha} & \text{for } 0 \leq x \leq \infty \\ 0 & \text{for } x < 0 \end{cases},$$

where x is the amount of pesticide, α and β are the parameters to be estimated (Fishman, p. 211).

Empirical data for this function are quite scarce, unfortunately. With no other alternative, it was necessary to combine results from two independent studies in order to estimate α and β compatible to field conditions. The estimated values are $\hat{\alpha} = 0.08605$, $\hat{\beta} = 1.00727$. Data from Shipp, Lindquist, Brazzel were used to estimate the function. x is in terms of unit per cage in their experiment. To convert x to a pounds per acre unit, a multiplier of 0.0314 is used which was calculated from a study by Mistrie and Gaines. Kill rates in the simulation were computed according to the estimated parameters of equation (1).

Economic Objective Function

The economic problem under deterministic conditions for a single cotton producer is assumed to be a maximization of the net returns from his cotton fields.[2] A cotton crop is composed of lint and seed. Hence the gross revenue is defined by

$$(2)\qquad R \equiv y_L P_L + y_S P_S,$$

where y and P are yield (lbs./acre) and price (\$/lbs.), respectively, and L and S denote lint and seed. Total cost of production can be divided into variable and fixed costs. In this case, only costs associated with the control of pests are regarded as variable, while all other costs (like labor, machinery, fertilizers, and land) are assumed to be fixed: P_L and P_S are the product prices minus harvest cost. The total variable cost is defined by

$$(3)\qquad C \equiv P_x \sum_{i=1}^{T} x_i + \sum_{i=1}^{T} S_i,$$

where P_x is price of pesticide including cost of application (\$/lb.); x_i is the amount (lbs./acre) of pesticide applied at period $i = 1, 2, \ldots, T$, where each period is equal to four days; s_i is the setup cost per treatment ($S_i = 0$ if $x_i = 0$; $S_i = S$ if $X_i > 0$). The setup costs are not proportional to the amount of pesticide use but linked to the decision to spray. These are usually contracted on a per acre basis. Current regulations do not allow cer-

[2] The authors feel that data gathered in the next few years will allow treating a more realistic economic problem under uncertainty.

tain of the dosage levels used in this study; however, this study may help reevaluate them. The net return is given by

(4) $$\Pi = R - C;$$

and our problem can be stated as

(5) $$\text{Max} \quad \Pi = R - C, \text{ for } i = 1, 2, \ldots, T, \; x_i \geq 0,$$

subject to (1), (2), (3), and relations of the simulation model described above, which is capable of evaluating R and C as a function of any given set x_i. It is assumed that the single farmer is not large enough to affect the regional pest dynamics nor can he affect either price of cotton or price of pesticides.

In this study the assumption is made that the boll weevil is the only key pest threatening cotton. This assumption is valid in some areas of cotton production in the Southwest, but it does not apply to areas where the bollworm and other arthropods are threats as pests.

To maximize equation (5), it is necessary to satisfy

(6) $$\Pi_{x_i} = 0, i = 1, 2, \ldots, T,$$

where Π_{x_i} denotes a partial derivative of net return with respect to x_i. (Equation (1) and sensitivity analysis done with the model do not give grounds for the potential existence of multiple local optimum points. However, this issue cannot be determined analytically.) However these derivatives are unobtainable analytically due to the highly nonlinear behavior of R which, in addition, involves dynamic interrelationships among the x_i's. Regev, Gutierrez, and Feder did obtain the partial derivatives analytically, but only because the alfalfa and its pests are by far simpler in their behavior than the cotton-boll weevil system and due to other simplifications imposed on this model. So, the method of obtaining the solution had to consider this difficulty.

The Solution Method

A modified version of the Fletcher-Powell-Davidson method for nonlinear optimization has been adapted (for details, see Talpaz, pp. 501–502). This algorithm calculates the gradient vector and the Hessian matrix numerically by repeated evaluations of the cotton-boll weevil simulation model and subject to equations (1)–(4). The cotton growing season potentially vulnerable to the boll weevil attacks begins with emergence of the first square and ends when bolls are no longer susceptible to attack. Depending on variety and location, this season is approximately 100 days. Taking pest population dynamics, cotton growth rates, and management decisions into consideration, this season was divided into twenty-five time periods, each four days long. Hence, our problem is to find x_i, for $i = 1, 2, \ldots, 25$ such that Π is maximized.[3]

Results of a Demonstration

A demonstration was carried out with the following assumptions fed to the computer, representing the "basic" run: (*a*) weather conditions (temperature, humidity, and solar radiation curves for the season) comparable to the Brazos Bottom, Texas; (*b*) cotton variety is Tamcot SP-37; (*c*) pesticide is methyl-parathion, with a price of $4.00 a pound of active ingredients (which includes spray costs), setup cost of $5.00 per application; (*d*) cotton price, $0.45 per pound of cotton with seed, $0.55 per pound of cotton (lint only). These are prices minus harvest costs. Boll weevil immigration rates for the Rolling Plains of Texas, based on Wade and Rummel publication, were assumed to be 90, 87, 85, 170, 170, 200, 100, 20, 15, 15, 5 weevils per day per acre for each of the first eleven four-day periods, respectively. The optimized strategy for this "basic" run resulted from pesticide applications on periods 2, 4, and 9, which are equivalent to 8, 16, and 36 days after the emergence of the first square, with quantities of 1.83, 1.32, and 3.74 pounds per acre of pure substance, respectively, and net income (as defined above) of $216 per acre.

In addition to this information, the program provides for each period a detailed account of pest population of weevils according to their age groups and cotton fruit population.

Two additional sensitivity runs were made. In run 2, a doubled price of pesticide was assumed, i.e., $8.00 per pound, keeping all other assumptions unchanged. Results show a decrease of pesticide to the levels of 1.29, 1.11, and 0.97 pounds per acre applied at the

[3] The computer program is written in APL-SV language. It costs $15–$20 to obtain a solution on an AMDHAL computer.

same periods as before. This represents a decline of pesticide use of 51.2%. Net income was down to $191 per acre.

In run 3, the price of cotton was increased by 50%, leaving everything else the same as in the "basic" run, i.e., $P_L = 0.825$ and $P_S = 0.625$ ($/lb.). Optimal policy in this case calls for the same three applications with quantities 1.50, 3.94, and 3.81 pounds per acre with two additional "mini" applications (which can be practically ignored) at periods 8 and 12. This increases the amount of pesticide use by more than 34% over the "basic" run. Net income was $343 per acre.

Discussion of Results

Results of the three runs seem to be reasonable, economically and biologically. It is increasingly recognized among entomologists that the boll weevil causes damage to cotton yield only at a "time window" which takes place before fruiting reaches midseason. Because of the plant's capacity to compensate for early injuries, early damage may be offset somewhat. Late in the season the weevil can attack the set bolls; however, it prefers the younger squares. Such attacks are not harmful because the squares do not have sufficient time to mature even under a pest-free situation. It is somewhere around midseason when damages can be economically significant. The potential for increases in bollworm damage due to destruction of beneficial insects is not considered. The optimal policy, independently obtained here, appears to aim these treatments at that critical "window." Observing the immigration rates (see above), it appears that the timing of pesticide application was selected such that major weevil immigrants could be destroyed. Due to setup costs, it pays to treat at certain intervals instead of applying smaller doses at each period in the "window." This fact contributed to the low number of applications.

The sensitivity analysis shows that timing of pesticide applications is robust. Pesticide total use is sensitive to a change in pesticide price and to a change in price of cotton. These conclusions could be expected. Pesticide costs still remain marginal compared to total costs, which leads to considerable adjustments in response to price changes. Increases in cotton price are important, causing producers to protect their higher valued yield by increasing pesticide use. These results show that pesticide use is sensitive to prive variations of both input and output. Yet, in the real world, one may find more rigidity in dosage applications, perhaps a result of technical arrangements between growers and the spraying company or decisions taken under uncertainty conditions.

Concluding Remarks

A detailed model of a cotton plant-boll weevil system has been built. Optimized policy for pesticide application under deterministic conditions has been achieved through a dynamic nonlinear optimization technique. There was no need to simplify the model to obtain control optimization. The model is flexible enough that if additional detailing is necessary in the future, it can be incorporated easily into the model where the only consideration is computer memory capacity and/or computer time.

Future research is needed to establish the biological relationships between boll weevil and other pests, making the model more general and applicable. Once completed, extensions to this model seem to be straightforward. More testing and applications from different regions and cotton varieties is needed to build confidence in its use. Such confidence may then lead to extension of this methodology to other crops and pests. An important improvement of the model would be to obtain an optimal strategy under risk conditions. This requires more information about the random behavior of the system. Work on the model continues in many locations and could provide in the future the information needed for optimizing strategy under risk.

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Active Learning, Control Theory, and Agricultural Policy

Gordon C. Rausser

In the evaluation of key agricultural policies, a number of critical uncertainties arise for which little in the way of empirical evidence has been accumulated. The typical departmentalization within the agricultural economics profession fails to offer any hope of properly assessing these uncertainties. One approach that integrates the separate tasks of system analysis, econometric estimation, optimization and more pragmatic data collection and summarization efforts is adaptive control. This framework effectively combines the characteristics of dynamic systems, uncertainties, and the active accumulation of information. Implications are drawn for potentially rewarding applications in agricultural and natural resource economics.

Key words: agricultural policy, closed loop, control theory, learning, open loop and measurements feedbacks, solution algorithms.

In recent years the potential variability of the world food system has become increasingly obvious. Especially during 1972–73, the magnitude of increases in farm product and food prices surprised almost everyone within the public as well as the private sectors. To U.S. government officials who were struggling to contain inflation, especially in the administered price sectors of the economy, this tremendous increase in food prices was indeed a bitter disappointment. Moreover, from the standpoint of existing price-forecasting models, it became clear that current perceptions and methods of predicting food price system events were no longer viable. Correspondingly, what in the short run may seem to be a desirable policy may lead in the long run to undesirable, even deleterious, results.

In the above setting, it remains crucial to isolate the basic nature of the agricultural and food system. Even in the face of changes which have occurred simultaneously and in magnitudes never before perceived, conventional wisdom seems intact. Generally, conventional wisdom characterizes the system by (Brandow) highly inelastic aggregate demand, low income elasticity of demand, rapid technological change, asset fixity, atomistic structure of the production sector, life cycles of plant and animal growth, the growing nature of inventories, climatic and weather uncertainties, labor immobility, and the demand for and the propensity of governments to intervene actively in the agricultural and food systems. One of the principal implications of these characteristics is instability. A policy frequently advanced for dealing with instability is inventory or buffer stocks. Such policies can assume many different forms and their effects are highly uncertain. Other instruments of government intervention are trade-oriented; they include export subsidies, export controls, foreign aid, import tariffs and quotas, concessional sales, and efforts to liberalize trade relations. The last set of policies often applied to food and agricultural systems are chiefly oriented toward production and include regulation of output prices, quantity control, input controls, and input taxes and subsidies. Here, due largely to uncertainty, the issue of price versus quantity controls becomes a nontrivial problem (Rausser and Riboud).

In assessing each of the above policies, a number of critical uncertainties arise for which little empirical evidence has been accumulated. For example, in the context of

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trade policies, is the paradigm offered by neoclassical theory sufficiently robust or must governmental behavior and resulting trade distortions be introduced endogenously? In the case of buffer stock policies, the nature of the relevant demand and supply relationships becomes critical. The distribution of gains and losses from price stabilization can be drastically altered by various specifications of these relationships. Moreover, the risk levels within various commodity systems and the distribution of risk and their effects on behavior have certainly not been precisely quantified. Much remains to be learned about the equity effects of such policies along both qualitative and quantitative dimensions. In a more general sense, to provide useful policy assessments, much remains to be learned about the (*a*) nature of structural change, (*b*) parameter variation, and (*c*) expectation formation patterns of various participants in food and agricultural systems.

Over the last few decades, a number of methods have been developed to assist us in the assessment and evaluation of alternative policies. Some of these emanate from the work of both electrical engineers and economists on control theory. As early as 1966, Fox, Sengupta, and Thorbecke provided much direction to the development and application of these methods by economists. Subsequently, the American Agricultural Economics Association held a special session at the winter meetings in 1969 on the applicability of control theory to agricultural policy and decision making. Emphasis here was on deterministic control theory which had been widely applied to various agricultural decision problems. These methods have been extended to stochastic as well as adaptive control formulations. Such formulations have been emphasized in the six conferences held by the National Bureau of Economic Research over the period 1972–77. An indication of the apparent value of these methods is reflected in a glowing article which appeared in the May 1973 issue of *Business Week:* "Control theory has swept into the economic profession so rapidly in the past two or three years that most economists are dimly aware that it is around. But for econometricians and mathematical economists and for the companies and government agencies that use their skills, it promises an improved ability to manage short run economic growth investment portfolios and corporate cash positions."

Although these methods have not achieved the degree of success implied by this report, their potential as a supporting device for governmental and private decision making remains promising. In the case of agriculture, this potential is documented in the recent volume on the survey of quantitative methods in agricultural economics (Judge et al.). The work surveyed in this volume emphasizes the importance of fully integrating the array of various quantitative approaches to problem solving and testing of theoretical constructs. Econometric methods, optimization, systems, and simulation or more pragmatic data collection efforts should not be viewed as separable tasks. Instead, problem-oriented research requires that these apparently separate tasks and associated methods be more fully and effectively integrated.

One framework that provides a consistent approach to this integration is provided by adaptive control theory. The adaptive control formulation includes as special cases the deterministic as well as stochastic versions of control theory. This approach to economic policy corresponds to Bellman's (pp. 198–209) as well as Feldbaum's (pp. 24–31) third class of control systems, which is characterized by some unknown quantities about which uncertainty changes by learning as the process evolves. This class includes the active accumulation of information, i.e., the accumulation of information does not take place independently of the control process. In fact, optimal adaptive controls require a simultaneous solution to a combined control and sequential design of experiments problem and thus are dual in nature.

In the next section, we examine the adaptive control framework by first formulating the general problem and defining the associated information elements. In particular, control policies are classified with regard to the information usage. This classification, although not exhaustive, allows various adaptive control solution approximations to be generated. In order to motivate the need of these approximations, in the third section we present a simple two-period problem to illustrate the inherent analytical difficulties in obtaining solutions. This problem is also utilized to demonstrate the distinction between passive learning and active learning.

We briefly survey schemes based on the former approach. These schemes admit only accidental learning, and thus do not involve an experimental dimension. Then we present various actively adaptive schemes representing a generalization of what Raiffa and Schlaifer have referred to as "preposterior analysis." For these schemes, the value of information is anticipated by using statistics of future measurements via algorithms based on the notion of closed loop control. Such control schemes involve an experimental dimension that probes the system in anticipation of the value of information to be derived from future observations. This section also records the available results on the comparative performance of both passive and active schemes. Finally, in a concluding section we present a brief overview of past and current research efforts as well as those issues of significance to the further development of adaptive control methods.

General Model Specification and Classes of Stochastic Control Problems

For the general adaptive stochastic control problem, the state of the system at time $k, x(k)$ is presumed to evolve according to

$$(1)\quad x(k+1) = f\{k, x(k), p(k), u(k), v(k)\},\quad k = 0, \ldots, N-1,$$

where $p(k)$ is the vector of parameters, $u(k)$ is the vector of controls or decisions applied at time k, and $v(k)$ is the process noise.

At time k, prior to applying the control, the state of the system $x(k)$ may be observed. However, for many agricultural economic problems, the state of the system cannot be measured perfectly due to sampling imperfections and the like. Hence, as a result of measurement noise $w(k)$, only partial observation $y(k)$ may be achieved,[1] where

$$(2)\quad y(k) = h[k, x(k), w(k)],\quad k = 1, 2, \ldots, N.$$

The variables $x(k)$, $p(k)$, $u(k)$, $v(k)$, $y(k)$, $w(k)$ are vectors with the following dimensions: $(n \times 1)$, $(r \times 1)$, $(m \times 1)$, $(n \times 1)$, $(s \times 1)$, and $(s \times 1)$, respectively. The statistics of the random elements are $x(0)$, $\{v(k)\}_{k=0}^{N-1}$, $\{w(k)\}_{k=0}^{N-1}$ and the functional form $f(.)$, $h(.)$ are assumed known.

The objective function is represented by the minimization (maximization) of the expected cost (gain),

$$(3)\quad J = E\{C(N, X^N, U^{N-1})\},$$

where the expectation is taken over all the underlying random variables, C is a real valued function, and U^k and X^k, $k = 0, \ldots, N$ are defined as:

$$(4)\quad U^k \equiv \{u(i)\}_{i=0}^{k},\ X^k \equiv \{x(i)\}_{i=0}^{k}.$$

Accordingly, the minimization of the expected cost is performed with respect to the sequence of decisions U^{N-1} applied during the N-stage control process.

The set of observations from time $k = 1$ to time j, after the sequence U^{j-1} has been applied, is denoted by

$$(5)\quad Y^j \equiv \{y(k)\}_{k=1}^{j},\quad 1 \le k \le j \le N.$$

One possible additional specification frequently found in the literature (Rausser and Pekelman) treats the case where the vector of parameters $p(k)$ evolves according to

$$(6)\quad p(k+1) = g[k, p(k), \theta(k)],$$

where $g(.)$ and the statistics of $p(0)$ are known. Clearly, $p(k)$ can be regarded as a state and augmented to $x(k)$ so that the new state vector is

$$(7)\quad x'(k) = [x(k), p(k)].$$

The various informational elements contained in the above system may be captured by a few additional definitions. In particular, the information about the dynamics of the measurement system between time *0* and time j may be denoted as:

$$(8)\quad m^j \equiv \{h(k, \ldots,)\}_{k=0}^{j},$$

i.e., m^j represents the structure of the observation program up to time j. Along with this definition, the joint density distributions of the random variables prove useful in characterizing alternative adaptive control schemes,

$$(9)\quad L^k \equiv P[x(0),\quad p(0),\quad \{v(i)\}_{i=0}^{N-1}, \{\theta(i)\}_{i=0}^{N-1}, \{w(i)\}_{i=0}^{k}],\ k = 1, \ldots, N-1,$$

[1] This specification of the measurement equation (2) has been extended (Rausser and Howitt) to include the possibility of measurement controls. An additional variable that can be directly controlled in many decision-making processes involves measurement precision. Under certain conditions, these authors demonstrate that the measurement control problem is separable from the behavioral control problem which involves the optimal setting of (u_k) in equation (1).

$$L^0 \equiv P[x(0), \quad p(0), \quad \{v(i)\}_{i=0}^{N-1}, \quad \{\theta(i)\}_{i=0}^{N-1}].$$

Note that this representation implies that L^0 does not contain any information on the measurement statistics.

In the above specification, dynamic economic systems are characterized by pervasive uncertainties. It allows a variety of different types of uncertainty to be analyzed. These types include (*a*) the errors $v(k)$ which are recognized generally as additive disturbances in econometric models; (*b*) the parameters $p(k)$ which are specified as nonstationary but admit as special cases random, stationary parameters and the more typical econometric formulation of constant, unknown parameters; and (*c*) measurement errors $w(k)$ which introduce issues akin to those found in the "errors-in-variables" econometric literature.

The various classes of stochastic control problems can be defined by the amount of information utilized to determine the control for each period. These classes are not exhaustive and are advanced only to provide some overall structure. It is particularly important to note the difference between the feedback policy and the closed loop policy. For both policies, available information is utilized to determine current decisions; however, only in the case of the latter policy does the decision maker anticipate future information and take it into account in his current control calculations.

Alternative Policies

The open loop policy. During the horizon $(0, \ldots, N-1)$, no information is available to the controller, i.e., all decisions are made on the basis of the information available at time 0. Therefore the control rule has the form

$$(10) \quad u(k) = u[k, U^{k-1}, L^0], \quad k = 0, \ldots, N-1.$$

The open-loop feedback policy. At each period k, as the data becomes available, the controller observes this information; but in his determination of the control, he assumes that no future observations will be available. Hence, the control rule in this case has the form

$$(11) \quad u(k) = u[k, U^{k-1}, Y^k, m^k, L^k], \quad k = 0, \ldots, N-1.$$

The M-measurement feedback policy. For this policy, in addition to the current data, the subsequent M-measurements with their statistics are available to the controller, i.e., the control decision is based on the current measurement and M additional anticipated measurements. Here we have:

$$(12) \quad u(k) = u\ [k, U^{k-1}, Y^k, m^{k+M}, L^{k+M}], \quad k = 0, \ldots, N-1.$$

The closed loop policy. In this policy the current information as well as all future anticipated information and their corresponding statistics are taken into account, i.e., it is known that the loop will be closed through all periods of the planning horizon. For this policy, the rule will have the form

$$(13) \quad u(k) = u\ [k, U^{k-1}, Y^k, M^{N-1}, L^{N-1}], \quad k = 0, \ldots, N-1.$$

Note that for a deterministic system all four classes are identical.

Illustration of Alternative Policies

Further insight into the above policies may be gained by examining a stochastic problem which is not adaptive in its parameters, namely, a production or acreage control scheme where the decision variable is the quota imposed, and observations are made on demand, supply, and inventory carryover realizations. For a N-period problem, the open loop policy will consist of N-decisions, one for each of the N periods. These quota decisions will be made at time zero on the basis of the inventory level at that time and the demand and supply distributions for all future periods. No further observations on future demand and supply realizations will be made. In the feedback policy, the quota decision is made in each period k after observation of the realized demand, supply, and inventory of that period. However, it will be assumed that no future observations will be available, i.e., corrective quotas in future periods will not be possible. Note that what constitutes a feedback policy for the horizon $[0, N]$ is actually the set of a first-period solutions of an open loop policy with horizons $[0,N], [1,N], \ldots, [N,N]$. This policy will differ from what is commonly coined the "rolling horizon" problem, i.e., when the length of the horizon remains constant and the set of first-period solutions is generated for the horizons $[0,N], [1, N+1], \ldots, [N,2N]$.

To illustrate the M-measurement policy,

consider the case where during the N-period problem observations of demand, supply, and inventory realizations will be available only for the first M periods. Then the quota decision at time $k = 0$ will be based on the knowledge that corrective quotas can be made during the coming M periods. In period $k = 1$ there will be only $M - 1$ corrective quotas in the future and, therefore, the policy will be an $M - 1$ measurement policy; and, in general, for period k, $k \leq M$ we have an $M - 1$ measurement policy until $k = M$ where the policy will become a feedback or zero measurement policy. The closed loop policy is obtained when the expected effects of current quotas on estimated parameters of future demand, supply, and inventory realizations are taken into account for all subsequent periods. For an N-period planning horizon, the closed loop policy is an N-measurement policy.

In general, the optimal policy for a stochastic control problem will be closed loop. However, due to analytical difficulties in deriving the closed-loop control rule, the other policy classes are commonly used as an approximation. The order of the analytical difficulty usually decreases as we reduce the amount of information available to the decision maker.

Approximate Solutions

To properly classify various schemes, it is important to first distinguish between approximations performed on the original system and those performed in the process of deriving the optimal rule. Most approximations resulting from the first approach will fall into the category which we define as passively adaptive schemes, while the latter type approximations will generally be actively adaptive. In order to motivate the need for approximation, we solve a simple two-period problem and show the analytical difficulty in deriving the optimal solution. We utilize this example to illustrate as well the nature of passively adaptive versus actively adaptive solutions.

Consider the two-period problem

$$J = \min E \sum_{k=1}^{2} (x_k + 1/2 \cdot u_k^2), \tag{14}$$

subject to

$$x_k = \alpha u_k + \epsilon_k, \; k = 1, 2, \tag{15}$$

where $\epsilon_k \sim N(0, q)$ for $k = 1, 2$; cov $(\epsilon_1, \epsilon_2) = 0$; $E(\alpha, \epsilon_k) = 0$; and α is the unknown parameter with the prior distribution at time $k = 0$ given as

$$\alpha \sim N(\alpha_o, \sigma_o). \tag{16}$$

The first decision will be u_1, which when imposed will result in x_1. After the realization of the random variable x_1, the distribution of the parameter α will be reestimated. Using a Bayesian procedure, the *a posteriori* mean and variance of α, denoted as α_1 and σ_1, are

$$\alpha_1 = \frac{\alpha_o q + \sigma_o \, u_1 x_1}{u_1^2 \sigma_o + q}, \text{ and} \tag{17}$$

$$\sigma_1 = \frac{\sigma_o q}{\sigma_o u_1^2 + q}. \tag{18}$$

Clearly the selection u_1 and the resulting x_1 will affect these estimates. In particular, if $|u_1|$ is large, the updated variance of α will be small. Hence, a large control value may assist in learning about α. In order to determine the optimum value of u_1, the value of additional information on α must be captured. This value, in the context of a given control problem, allows the trade-off between current control and learning for future control to be estimated. If the estimate of α_1 can be improved, a better decision u_2 obviously can be made. This argument may be referred to as the active learning part of the decision because deliberate learning in terms of improved estimation is exercised.

The other dominant consideration in determining u_1 is current control, i.e., the impact on the objective function for the current period. Clearly, the first period control which minimizes current expected cost is $u_1 = -\alpha_o$; this setting must be weighted against the desire to set $|u_1|$ at higher levels to achieve additional learning. In this particular example, the only interaction between the two periods is through learning. The underlying system is inherently static because the state x_{k+1} is independent of x_k. Thus, for the simple representation we can clearly delineate the current control and the dynamic one which corresponds to learning.

The solution to the above problem can be pursued by the use of dynamic programming. For the second period, we obtain the solution $u^*_2 = -\alpha_1$ with the associated perfor-

mance level $J^*_2 = -\frac{1}{2}\alpha_1^2$. Note that $\alpha_1 = E\{\alpha/x_1, u_1\}$, i.e., α_1 is the *a posteriori* mean of the parameter after the decision u_1 is taken and the realization x_1 is obtained. Substituting (17) for α_1 in J_2 and taking the expectation, we obtain

$$(19) \quad J^*_2(u_1) = -\tfrac{1}{2}\left(\alpha_o^2 + \frac{\sigma_o^2 u_1^2}{u_1^2 \sigma_o + q}\right).$$

From the standpoint of the first, or current period, expression (19) refers directly to the cost of learning. Since this cost is negative, setting u_1 so as to enhance learning is beneficial to future control.

The relevant performance measure for the first period resulting from the application of dynamic programming and the expectation operator is

$$(20) \quad J^*_1 = \min_{u_1}\left\{(\alpha_o u_1 + \tfrac{1}{2}u_1^2) - \tfrac{1}{2}\left(\alpha_o^2 + \frac{\sigma_o^2 u_1^2}{u_1^2 \sigma_o + q}\right)\right\},$$

where the terms $\alpha_o u_1 + \frac{1}{2}u_1^2 = C(u_1)$ refer to direct control and the remaining terms refer to the learning measurement appearing in $J^*_2(u_1)$. Clearly, the optimal selection of u_1 must achieve some balance between present control and learning for future control.

Unfortunately, the minimization of the two "dual" cost terms in (20) is not a simple analytical task; the optimal decision rule is highly nonlinear in the control variable u_1. The current control, $C_1(u_1)$, and the future learning, $J^*_2(u_1)$, components of the dual cost suggests that (where α_o is assumed to be positive): (*a*) if q is small, the optimal u_1 is approximately $-\alpha_o$; (*b*) if q is moderate, the optimal u_1 lies to the left of $-\alpha_o$; and (*c*) if q is very large, the u_1 is approximately $-\alpha_o$. For case (*a*), the small value of q implies that unplanned (or accidental) learning is sufficient to reduce the updated variance (18), while for case (*c*) a large value of q suggesting high noise intensity implies that planned learning does not pay off and, thus, there is no need to look beyond a one-stage optimization problem. Only if q is moderate size does planned learning prove beneficial. Note that similar conclusions can be drawn for different values of σ_o. (In fact, the optimum u_1 is determined by the ratio q/σ_o and σ_o.)

Although the system (15) is static, dynamic interactions are introduced by the reestimation of α after the realization u_1, x_1, i.e., the effect of u_1 and x_1 on α_1 and, therefore, on the decision in the second stage. The decision u_1 in the first stage and, hence, the realization x_1 may improve the estimation of α and consequently the second period decision u_2 along with the resulting payoff J_2. Hence, when the decision u_1 is made, the value J_2 is taken into account. This is represented by the second term in expression (20). However, even for this static system, to proceed analytically one more period backward would be impossible since a closed form solution for u^*_1 cannot be found. Therefore, some approximations are required to obtain a solution.

When the decision is concerned with system parameter learning as well as with the control, we will call it active learning. If the active learning of α is ignored, i.e., if we eliminate the second term in the J^*_1 expression, the problem will be completely static and the optimal strategy is simple: $u^*_1 = -\alpha_o$ and $u^*_2 = -\alpha_1$. The learning element will still exist, since α will be reestimated; however, it will be completely passive, i.e., the amount of learning about α will not deliberately be directed by any previous decision. Various approximation approaches involve the partial or complete neglect of active learning. In this example, an obvious approximation is generated by adding a simplifying assumption to the original system. Specifically, the mean estimate α_1 is treated as though it were the true value of α. This assumption results in the removal of the learning term in (20).

An example of an approximation performed during the derivation of the rule, rather than on the basic system, would be an expansion up to a second order of the active learning term in J^*_1 around some nominal values. If we select the nominal value in this case to be $u_1 = -\alpha_o$, we will obtain after the expansion to the second order and some simplifications.

$$(21) \quad J_1^0 = \min_{u_1}\left\{(\alpha_o u_1 + \tfrac{1}{2}u_1^2) - \tfrac{1}{2}\left(\alpha_o^2 + \frac{\sigma_o^2 \alpha_o^2}{\sigma_o \alpha_o^2 + q}\right) - \frac{\alpha_o \sigma_o^2 q}{(\alpha_o^2 \sigma + q)^2}(u_1 + \alpha_o) + \tfrac{1}{2}\left[\frac{3\alpha_o^2\sigma_o^3 q - \sigma_o^2 q^2}{(\alpha_o^2\sigma_o + q)^3}\right](u_1 + \alpha_o)^2\right\}.$$

For this expression, a closed form expression for u_1 exists, and multiple-period problems can

then be solved recursively. Note that the active learning part is approximated but still appears in the control rule.

The first approximation generates a control rule with passive learning, while the second form preserves elements of active learning. For many of the common adaptive control approximations, this general observation holds. That is, when the approximation is on the original system, the control rule is often passive; while if the approximation is performed in the deviation of the rule, some of the active learning elements are preserved.

Passive Adaptive Schemes

The passive schemes which have been advanced to solve the adaptive control problem are simply generalizations of stochastic control methods found in Chow (1975) or Rausser and Hochman. They include updated certainty equivalents, various versions of open loop feedback, sequential stochastic and linear quadratic Gaussian schemes. All of these schemes involve some modification of original adaptive control systems and admit only accidental learning.

Updated certainty equivalence. In this scheme it is assumed that the certainty equivalence (CE) property holds, i.e., that the mean value of all random variables in the system is their true value. For every period k, the current estimate of the mean value of the random variables is used to replace the random variables and the problem is solved in a deterministic mode. In terms of the information used, the CE control rule has the form

$$u^{ce} = u^{d}[k, U^{k-1}, Y^{k}, m^{k}]. \tag{22}$$

The rule is in feedback form, and the parameters and the states are reestimated every period as additional data becomes available. However, no account is taken for future measurements and thus future uncertainty.[2] Note that the certainty equivalent rule is the same as the deterministic rule $u^d(\cdot)$. However, the time paths of the optimal CE controls and associated state variables and criterion function can differ substantially from their deterministic counterparts. This rule and the associated certainty equivalence property does not hold for the general adaptive control problem as a result of the nonlinearity introduced by the product of the parameters and the states.

The CE result is closely related to the separation property employed in electrical engineering literature (Witsenhauser). This property holds if the information about the parameters and the states utilized in the optimal control rule can be captured by their mean value where the functional form of the feedback equation may differ from the deterministic rule $u^d(\cdot)$. For the CE formulation, the control rule is equivalent to the deterministic one and the random variables can be replaced by their mean values. The separation property has only the second characteristic, and therefore the CE property implies the separation property but not vice versa. (The word separation is used to indicate the complete independence between the procedures used for estimation of the mean value and those used for the control calculation.)

Open loop feedback. This approach was originally suggested by Dreyfus and has been investigated by Aoki, Bar-Shalom and Tse (1975), Curry, Ku and Athans, and Tse and Athans. At time k when the control u_k is calculated, it is assumed that no measurements will be obtained in the future. Although the stochastic elements of the parameters as well as those of the states are taken into account, it is assumed that the covariance of the parameters will remain the same for all future periods. The use of information in this scheme is identical to our previous definition of the feedback class.

In the process of deriving the optimal rule for these schemes, we face the difficult task of determining the expectation of the product of the parameters and the states along with the parameters and the controls. Tse and Athans, for example, avoid the problem by assuming that the parameter multiplying the state is nonrandom, while Ku and Athans assume that the expected product of the parameter and the state is equal to the product of the expectation. Both of these assumptions obviously represent misspecifications.

Sequential stochastic control. Rausser and Freebairn (1973), Zellner, Chow (1975), and Prescott have investigated this approach. The derivation of the control rule is based on the assumption that observations will indeed be available in the future. However, they will not be used to adapt the probability distributions on the parameters. Chow (1975) has referred

[2] Under certain well known conditions (f linear, C quadratic, and the only stochastic elements are the $v(k)$'s, assumed additive and independent), stated first by Simon and Theil, the CE solution is optimal. Under these conditions, nothing can be gained by utilizing information on future measurements and uncertainty.

to this approach as control without learning. For the case of a linear system and quadratic objective function, the optimal rule here is linear in the mean value and variance of the state. In essence, this approach is a member of the open loop feedback class but is distinguishable from the studies in that area because the unknown parameters are treated as independent identically distributed random variables for each period of the planning horizon. Nonetheless, as with open loop feedback, the approach ignores the possibility of ongoing estimation in the derivation of decision rules.

Linear quadratic Gaussian approximations. This scheme is thoroughly surveyed in Athans. If the system is nonlinear and/or the objective function nonquadratic, an expansion around some nominal values may be performed. The nominal values can be generated by imposing on the original problem the certainty equivalence assumption. Given nominal paths for the states, controls, and the parameters, the criterion may be stated as a quadratic function of deviations from these paths. One principal limitation of this approach is that it requires a nominal path for the parameter vector and subsequently minimizes deviations from this path. Clearly, the performance of this scheme will deteriorate rapidly if the uncertainty in the parameters or the input noise is "large." Moreover, this scheme is readily operational only for "tracking problems," i.e., where the nominal paths are treated as target trajectories. For meaningful applications, the target trajectories should be inherent in the nature of the decision problem.

Actively Adaptive Schemes

For situations in which the need for learning is explicitly recognized, knowledge can be accumulated in an active or dual control fashion. A number of schemes have been advanced in the literature for approximating actively adaptive control problems. Most of these schemes provide a consistent approach to the entire planning horizon and thus are approximations to the optimal closed loop solution. When these schemes are applied only to a subset of periods within the planning horizon, they approximate the M-measurement feedback solution. Each of these schemes views the future by utilizing in various fashions what is currently known about the information to be obtained later.

The key distinguishing feature of the alternative schemes is how they deal with the dependence of future information on present controls. For the general problems, (1)–(4), the information state along with the optimal cost-to-go (value function) associated with each information state must be characterized. The information state, denoted by ψ_k, is directly influenced by the conditional density, $p(x(k)|Y^k,U^{k-1})$. The general expression for how future observations will be made and utilized may be represented by the optimal cost-to-go, $I^*\{\psi_{k+1}, k+1\}$. Given these definitions along with a criterion function (4), which is separable across k, a stochastic dynamic programming solution expresses how $I^*\{\psi_k,k\}$ can be computed (in principle) recursively by

$$(23)\quad I^*\{\psi_k,k\} = \min_{u(k)} E(C[\boldsymbol{x}(k), \boldsymbol{u}(k), k] + I^*\{\psi_{k+1}[\psi_k, \boldsymbol{u}(k)], k+1\}|Y^k, U^{k+1}),$$

where $\psi_{k+1}[\psi_k, u(k)]$ monitors the evolution of the information state.

Two of the principal difficulties which arise in attempting to deal with (23) are (*a*) the information is either infinite dimensional or finite but grows with time, and (*b*) the optimal cost-to-go associated with the information state is generally not an explicit function. Approximations are offered by the following schemes to deal with these difficulties and thus all the schemes involve some simplification of the experimental or active learning dimension of dual control.

Tse, Bar-Shalom, and Meier (TBM). The most widely publicized actively adaptive scheme is based on the work of Tse, Bar-Shalom, and Meier; Bar-Shalom, Tse and Larson; and Bar-Shalom and Tse (1976). In essence, the wide-sense dual control procedure advanced by these authors admits all the basic types of uncertainty including measurement errors and decomposes the complete adaptive control problem into three components (*a*) current control, (*b*) future deterministic control, and (*c*) a future perturbation control. The perturbation, or experimental control component, is partitioned into a caution and probing term. The caution term reflects the effects of uncertainty at time k and subsequent system noise on the criterion function. The probing term summarizes the effect of uncertainties when subsequent decisions are made.

To handle two previously mentioned difficulties surrounding (23), TBM approximate the information state by maintaining only

the first two moments of the state estimate, namely, the mean and covariance updated estimates. These updated estimates can be computed by any one of a number of methods including the extended Kalman filter, second order filters, or the optimal filter (Jazwinski). The optimal future benefits or cost-to-go are then associated with this approximate information state at time $k + 1$. Moreover, the optimal cost-to-go is also approximated. This approximation is motivated by results which are available for the special class of linear-quadratic-Gaussian problems. Clearly, if the nonlinear joint control estimation problem can be somehow transferred into a linear quadratic Gaussian problem, an explicit form of the optimal cost-to-go is readily available. These authors make this transference by associating with each control setting u_k a future (fictitious) nominal control sequence. The choice of the nominal is quite flexible and dependent upon the class of problem under consideration. For each nominal control trajectory, there is a corresponding nominal state trajectory and trajectory of variances and covariances. Perturbation analysis is then carried out around these nominals from which approximate cost-to-go can be obtained that explicitly reflects future learning and control performance.

This approach involves a search over the space u_k, which consists of the following basic steps: first, select a value or values of u_k, then evaluate explicit functional relationship between u_k and the future covariance matrices, and, finally, use the resulting functional values to select the next values of u_k to examine. The scheme proceeds until satisfactory covergence is obtained. Clearly, this active scheme is computationally expensive and for systems with multiple controls, this expense will often prove to be prohibitive.

Chow (1975, 1976). An actively adaptive scheme also has been developed by Chow (1975) for the case of a quadratic but nonadditive criteria function, linear or nonlinear systems (1), and active learning with regard to the unknown parameters. For even the linear system specification, a complex nonlinear stochastic control problem is obtained which Chow's method approximates by applying a second order Taylor series expansion in perfectly measured states to the relevant value function. This expansion is taken about some tentative path for the states over the complete planning horizon using numerical differentiation. For nonlinear systems (1) Chow (1976) simply appends a first-order expansion of the system representation to obtain a linear approximation.

Although the Chow second order scheme is a closed loop approximation, it differs from the TBM approximation in a number of important respects. First, the TBM procedure allows measurement errors and treats the unknown parameters by augmenting them to the state vector while the Chow approximation does not. Second, while both approaches approximate the cost-to-go, in TBM the computation of the nominal path is made endogenously, i.e., the nominal trajectory for the entire planning horizon is a function of the current controls. In contrast, the Chow procedure treats the computation of the nominal path exogenously, and, thus, there is no assurance that the selected control path will conform to the optimal controls. Finally, TBM first applies the second order approximation followed by taking the expectation while the Chow algorithm reverses these steps. Hence, the Chow approach does not admit an explicit representation of the perturbation costs.

Adaptive covariance. One actively adaptive scheme which admits a relatively simple computational framework has been developed by MacRae (1972, 1975), who assumes no measurement noise, specifies the relevant parameter matrices entering a linear state equation as constant but unknown, and states a quadratic criterion. Essentially, the adaptive covariance approach alters the original dual control structure of the problem so that equations defining the approximate solution may be derived while maintaining a relationship between current controls and the future information state. Moreover, the equations defining the approximate solution readily admit terms associated with such economic concepts as the price of information and the value of estimation.

Given the above specification, the conditional mean and covariance completely characterize the relevant information state. MacRae simplifies the resulting problem by replacing unknown future observations by expected observations in the conditional mean and covariance equations, and obtains a temporally invariant result on the conditional mean updates. Hence, MacRae is left only with a covariance update equation. This covariance update relationship is quadratic in the controls and is introduced into the value function as a deterministic constraint along with an associated matrix of Lagrangian multipliers. Applying conventional dynamic pro-

gramming procedures, the augmented criterion function which remains quadratic in the control leads to analytical results for the control setting which are in linear feedback form. The obvious advantage of this approach is computational simplicity; it is readily tractable for the case in which the criteria function is quadratic in the states. Of course, to solve for those linear feedback controls, the relevant gain matrix mut be determined by solving a two-point boundary-value (TPBV) problem, which is tractable for rather large models (Rausser and Freebairn 1973).

Other adaptive control schemes. A host of other adaptive control schemes are also available which generally are applicable only to specialized structures. For example, Aoki advances schemes for problems in which the criterion is separable across the states and controls. Murphy has developed a solution for problems in which the only unknown parameters are those associated with the controls. Prescott, for the case of a single unknown, a single control and state, simply enumerates all possible solutions to determine the optimum.

Other schemes are attempts to approximate in one form or another the TBM approach. The Sarris and Athans two-step adaptive control takes into account future adaptation of conditional means but not the covariances associated with estimates of the unknown parameters. For this scheme, the solution does not involve an iterative system of equations. For the case of no measurement errors, Norman uses a first order expansion of the cost-to-go function. If the underlying probability distributions are non-Gaussian, Alspach has combined Gaussian sum approximation procedures and the M-measurement feedback control approach to obtain a solution scheme. Still other methods appearing under the headings of self-organizing control and trajectory shaping are also available (Rausser and Hochman). Under the former category, control schemes are treated as a fixed structural form with some adjustable parameters; the parameters are adapted by approximate parameter-specific or performance-specific methods. Trajectory-shaping methods are simple modifications of the linear quadratic Gaussian approach.

Comparative Performance of Passive and Active Control Schemes

A large number of comparisons of some of the alternative suboptimal adaptive schemes are available but almost all of these comparisons are based on rather questionable Monte Carlo simulation designs. This includes the work of Bar-Shalom and Tse (1976), Chow (1975), MacRae (1975), Norman, Prescott, Sarris and Athans, and Zellner. Generally this work examines only the case of a scalar-state and control variable, a quadratic criterion function, a linear system representation; and few, if any, of these studies employ any of the useful results from the statistical literature on sequential experimental designs. Moreover, due to the computational complexity and resulting costs of the various methods, the number of Monte Carlo simulations carried out are generally meager. Furthermore, the data base used for comparisons among various authors differ, and, thus, realistic comparisons of all the alternative suboptimal adaptive performance results are available which are worth briefly summarizing here.

Most of the results obtained thus far conform to a priori expectations. For example, Prescott finds for a static single equation system that the certainty equivalence approach is a reasonable procedure when uncertainty in the unknown parameter is small; specifically when the ratio of the prior's mean to its standard deviation is at least 4 in absolute value. When the ratio of the prior's mean to its standard deviation is smaller than 2, however, experimentation becomes a relevant consideration; i.e., it pays to select a decision larger in absolute value than the one which minimizes current expected loss in order to obtain additional information about the unknown parameter. Another result is that the more periods remaining in the planning horizon, the more important is experimentation.

MacRae (1972, 1975) finds that for a known parameter associated with a lagged state, it is possible for the adaptive covariance scheme to generate a more conservative current policy than the sequential stochastic rule. This result for the adaptive covariance scheme simply reflects the possibility that the best policy may well be to do a very little at first to avoid the relatively large cost of uncertainty and subsequently compensate later when the effect of the policy is known with more precision. This result is modified, however, if the parameter summarizing the relationship between lag and current states in the system representation is unknown. In this event, parameters associated with current controls and with lag stages can be correlated, and thus no general implications can be drawn about the relative magnitudes of

the policy variables. For this specification, although larger variances imply larger uncertainty involving the model parameters, large covariances imply more information, and there is no particular reason to presume that either the variances or covariances will dominate.

Several Monte Carlo simulations carried out by Tse and Bar-Shalom (1973) and their colleagues at Systems Control have evaluated the comparative performance of the TBM method with the certainty equivalence rule. For most cases examined by these authors, the TBM method gave substantial improvement over the certainty equivalence rule. In contrast, Chow (1975, pp. 267–76) reports a comparison among certainty equivalence, sequential stochastic, and the Chow active adaptive scheme for both a single equation and a two-equation system representation. He finds that the various rules do not lead to numerical values of the controls which differ to any substantial degree. An explanation of these apparent conflicting results is that the model representation employed in the Chow comparisons are more precisely estimated than those examined by Tse, Bar-Shalom, and others.

More recent results involving a comparison of the TBM method, the Chow actively adaptive scheme, the adaptive covariance scheme, and such passively adaptive schemes as open loop feedback and certainty equivalence have been reported by Bar-Shalom and Tse (1976). They found that the more sophisticated actively adaptive schemes did not always perform better than the open loop feedback or even the certainty equivalence rule. Similar small differences among the performance of the various algorithms were found by Sarris and Athans and Norman; in particular they did not obtain a distinct ordering among the certainty equivalent and sequential stochastic rules. Norman's results indicate that the performance of alternative schemes is problem-specific. Finally, when computational cost is explicitly considered, Norman isolates some special cases for which the open loop feedback as well as the certainty equivalence rule appear to be the most desirable schemes.

Empirical Applications

Among the best known applications of deterministic control is the early work of Gustafson on public inventories of feedgrains and the conceptual framework advanced by Burt for dairy pricing. Passive learning control applications include, among others, the work of Goreux, Kendrick, and Kim on cocoa market stabilization; of Rausser and Howitt on economic externalities; of Underwood and Pindyck on the payoff to the formation of copper and tea commodity cartels; and of Arzac and Wilkinson on the stabilization of livestock and feedgrain markets. These and other deterministic, stochastic, and passively adaptive applications are far too numerous to survey here. Although deterministic formulations often provide useful approximations to decision problems faced in agricultural and food systems, it is our view that the very nature of these problems require the explicit treatment of uncertainty. Hence, the advancement of stochastic control methods should receive increased attention from the profession. In the context of agricultural decision making under uncertainty, learning should be given explicit consideration.

The principal applications of active control schemes include the work of Pekelman and Tse on advertising, Rausser and Freebairn (1974a, 1974b) on agricultural trade policy, and a few studies dealing with a deliberate learning of demand functions parameters. Freebairn and Rausser have examined the inventory level to be carried from one period to another as well as pricing in wheat production, and Chong and Cheng have investigated pricing strategies for the introduction of a new product. Prior to these studies, Little (1966) advanced an adaptive framework with a specialized structure to investigate optimal advertising policies. In the management science literature, this work has been extended in a number of directions including a multivariate representation by Little (1977). In the context of commodity-marketing boards, Rausser and Hochman have provided a number of applications involving the selection of output prices, quota levels, the distribution of quotas among various producers, and in some instances the amount produced and sold. These applications explicitly admit nonlinear risk and the possibility of inventory accumulation. Along with these applications, Abel has examined a small macroeconomic model and Kendrick (1977) has applied active learning to a three-state variable macroeconomic model which included measurement errors. (For a thorough exposition of this approach, see Kendrick 1978.)

For many of the above applications, certainty equivalence, sequential stochastic, adaptive covariance, M-measurement feedback, along with the closed loop approximations advanced by Tse, Bar-Shalom, and Meier, and Chow (1975) have been employed. In general, these applications illustrate the benefits to be derived from the application of actively adaptive control schemes. The schemes were found generally to lead to more (less) extreme settings of the control level in the first (last) few periods of a given planning horizon than the passive control schemes. Furthermore, they generally resulted in control settings which exceeded in some instances by substantial amounts solutions obtained for the certainty approximations. In all of these applications, the expected gains derived from the application of active schemes exceeded all the various versions of the passive learning schemes.

Concluding Remarks

The various adaptive control schemes presented in this paper have been compared in terms of their utilization of information and the nature of the approximations they impose. As we have seen, existing simulation experiments do not offer any general conclusions about the relative performance of these schemes. Moreover, the recently developed approximation schemes are not based on arguments which imply improved performance, but instead they are motivated by numerical considerations. Unfortunately, no conceptual framework has been advanced on which to base an evaluation and comparison of the various schemes. Currently, the selection of an adaptive control method for a particular application can be determined only on a trial and error basis.

A conceptual framework which is analytically tractable is required which provides a clear exposition of the interaction between learning and control of a stochastic, dynamic setting. Our principal interest in the development of such a framework should be to obtain (*a*) measures of the learning capability for various adaptive schemes and their relationship with performance; (*b*) relationships of the structural properties of the optimal control scheme with the system structure, observation program, and performance criterion; (*c*) a clear indication of how information flows through the system are influenced by the control scheme and how both are related to overall system performance; (*d*) formal measures of the trade-off between computational complexity of the various schemes and their performance; and (*e*) tight bounds on the performance of alternative schemes (Faden and Rausser).

To be sure, for the number of applications of adaptive control to increase, the development of numerically simpler schemes with high capability of learning is critical. The search at times may be lengthy due mainly to the nonconvexity of the value function and the existence of multiple local extrema (Pekelman and Tse). Hence, the introduction of multiple controls would require for most active schemes a multidimensional search which may be numerically prohibitive.

In addition to the numerical issue, the development of new approaches should also consider aspects common to both private and public economic planning. The foremost element missing in the existing approaches is the capability of handling inequality constraints on the controls as well as the states. Although constraints on state variables, in general, can be assured to hold only in probability, their incorporation would enable us to solve the common resource allocation problem in an adaptive form where the coefficients of the return function as well as those specifying the technology could be continuously learned. Another element is concerned with whether or not the system representation is in structural form (current states depending upon other current state variables) or reduced form. All the adaptive control frameworks available in the literature assume the latter form but, unfortunately, many models in management science and economics are more naturally stated in their structural form. Furthermore, when these structural forms are highly nonlinear, it is not possible to derive a corresponding, unique reduced form. To deal effectively with this issue, sparse matrix and reduced gradient techniques have been utilized to achieve numerical accuracy in obtaining the reduced form for large scale models (Kendrick 1978).

Another issue of importance is model discrimination. A common criticism of adaptive control is that although significant parameter uncertainty may indicate the potential value of an adaptive control scheme, it may also indicate that the model is misspecified. Clearly, identification of the model structure is essen-

tial for any quantitative application. However, in the adaptive control framework, the experimentation may be directed toward the discrimination between competing models as well as learning of their parameters. Some work has been accomplished in this area (e.g., Saridis and Dao, Taylor) but much remains to be done. Although difficult, when different model representations appear equally possible, the appropriate adaptive control framework should be couched in terms of a simultaneous hypothesis testing and control problem.

A related issue is the impact of model misspecification (e.g., omitted variable, functional form) on the control and prediction performance of the various schemes. In the econometrics literature, the reestimation of parameters is usually justified by its ability to capture some of the model misspecification and hence reduce the prediction error. However, it is not clear that control performance is also enhanced by this procedure. Here again, much in the way of additional conceptual work on adaptive control schemes would appear to be necessary.

In the applications sphere, a number of decision problems arising in food and agricultural systems readily lend themselves to the adaptive control framework. There seem to be three general classes where the importance of adaptive control is apparent. The first is when a new system is introduced and its parameters are generally unknown. Examples would be the demand equation for a new product; the advertising-sales reaction for a new advertising copy of a new product; employee reactions to a new incentive scheme; the effects of a new technology, say a new seed variety or the production of gas from animal wastes; or the effectiveness of a new capital device in tapping existing natural resources or controlling the adverse (environmental) effects of natural resource utilization. The second case is where the system is established, but the parameters tend to vary over time. In order to ensure an acceptable control performance, these parameters should be monitored and actively learned. The third category, technically viewed as a subset of the first two, is where improvement of the model representing the system is sought. In particular, if two candidate models are competing and the control is determined on the basis of a composite model formed by a convex combination of the two, the weighting scheme can be modified continuously as a result of learning.

The above classes of empirical investigation suggest that some potentially rewarding applications of adaptive control include *inter alia* (*a*) the selection of private and public projects where the rate of return is unknown, but the selection process repeats itself; (*b*) promotion policy where a periodic decision is made on offering discounts, free samples, and the like; (*c*) periodic market surveys to determine likely consumer responses to product specifications; (*d*) public regulatory management where periodic monitoring decisions must be made to determine compliance and private sector response to regulatory controls; and (*e*) periodic agricultural as well as natural resource management decisions concerned with the effect of alternative input combinations and land allocations. The adaptive control framework indeed appears promising, but much additional evidence should be collected before its true value as a research tool is ascertained. Clearly, the jury is still out.

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Nontariff Barriers: Major Problem in Agricultural Trade

Jimmye S. Hillman

Nontariff barriers have become one of the key issues in agricultural trade policy and trade negotiations. Laws and regulations of a country, in addition to being directly protective, often give administrators wide leeway for interpretation which results in restrictive trade flows. The domestic agriculture of most developed countries is protected by one or more of the following: quantitative restrictions, licensing requirements, variable levies, export subsidies, minimum import prices, import calendars, state trading, mixing regulations, health and sanitary regulations, and standards and labelling. Ultimately, nontariff barriers must be negotiated like tariffs and other protective devices.

Key words: agricultural trade, international trade policy, trade restriction.

Agricultural trade negotiations have become increasingly complex. As the General Agreement on Tariffs and Trade (GATT) participants prepared for the so-called Tokyo Round of negotiations after the U.S. Trade Act of 1974 was passed, it was evident that there were different forces at work and different players in the commercial policy game as compared to other rounds of bargaining since World War II (for a historical review, see Tontz). The complexity of this "new situation" is due in large part to nontariff trade barriers originating from technology and the administrative bureaucracies, which have made commercial problems of the mid-twentieth century unique.

Nontariff barrier problems, along with agricultural policy issues, were pushed into the background during the Kennedy Round negotiations of 1962–67. There was an initial underestimation of the nature and level of the ultimate significance of such barriers to the countries involved. Moreover, a common agricultural policy for the European Community was being evolved during that period. Not until after formal negotiations were completed did participants in the bargaining realize the real importance of the nontariff barrier issue. The agricultural sector with its many difficulties and issues affecting nontariff barriers has now emerged on the world trade scene as a real problem child. This is no less true after the passage of the U.S. Food and Agriculture Act of 1977.

Agricultural protection and nontariff barriers are now being recognized as key subjects in broad areas of negotiations that are so necessary to policy formulation, decision making, and adjustment. Neither can be pushed aside any longer and ignored.

Nontariff barriers have been difficult to identify, rationalize, and negotiate by those dealing in the affairs of world trade. Moreover, there is a tendency for negotiators on trade problems to deal principally with policies related to tariffs, prices, and other quantitative indicators, and to leave in abeyance the more abstract and complex questions, even though these questions might be identified with some of the fundamental issues in trade liberalization. Be that as it may, international trade in agricultural products is of great importance to the world, and though it is beset by many problems of a nontariff nature, an attempt must be made to push understanding a bit further.

What Is a Nontariff Barrier?

The definition used for nontariff barriers here is any governmental device or practice other

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than a tariff which directly impedes the entry of imports, or exit of exports, and which discriminates against imports or exports; that is, which does not apply with equal force on domestic production or distribution.

Generally speaking, nontariff barriers include several types of policies or practices that interfere with or distort trade: (*a*) measures that restrict imports; (*b*) measures that provide assistance to domestic production in order to substitute for imports and which, in effect, promote exports; and (*c*) measures that provide direct assistance to exporters.

Nontariff barriers, then, are trade restrictions usually backed by national legislation or administrative law. Legislative and regulatory authority are based on the power of a nation to control its domestic commerce. In addition to including restrictions on international commodity and factor movement which arise because of clearly enunciated, well-defined and properly administered laws and regulations, nontariff barriers also include certain "potential" restrictions to trade. These barriers arise because of unwritten, ill-defined or irregularly administered laws and regulations. They result in considerable economic uncertainty. It is a well recognized fact in international commerce that producers in many countries refuse to initiate the processes of production and distribution necessary to penetrate markets which may be currently unrestricted because of the uncertainty of commercial policy in countries where the markets are located.

The protectionist principle is essentially the same whether it is invoked through direct or indirect methods of legislation or regulation or whether it is effectuated by a well recognized market impediment or as a psychological obstacle to trade on the part of all those against whom it is possible to discriminate. Whatever the technique used and whatever the reason for market exclusion, the result is a destruction of the benefits of geographical division of labor and industrial specialization. The inevitable consequence is a limitation of national and international incomes.

In the sphere of nontariff barriers, trade restrictions exist not only for "what the law says," but also because of what the legislative and regulatory potentialities are, or "what the law does not say." The element of uncertainty is far greater in the latter situation. Uncertainty of this type—political and administrative in nature—is far more elusive than the kind of economic uncertainty involved in price changes, because in the former there is little quantitative information available for evaluation. Observations about legal and administrative procedures are almost purely subjective; hence, it is necessary to point out that while a nation may be restricting "trade" very little by law or administrative edict, behind the scenes there may exist a deep sentiment against foreign competition and for protection, which may erupt in the form of a variety of market impediments once trade begins or increases to a sizable amount. What constitutes the restriction in this sense is the uncertainty surrounding trading potential because of what shippers and dealers think might be forthcoming after such moves as they might make have, in fact, been made.

Nontariff barriers to trade are also composed of dormant and temporarily unenforced legislation and regulations. In fact, these may constitute an even more dangerous obstacle to trade than unwritten law and arbitrary administration. Shippers move their products into what is a legitimate market, when suddenly the dormant law or regulation is enforced. This happens frequently in the case of perishables. For example, in the past when there were shortages of meat and poultry and when prices were abnormally high, local inspection and conditions of sale in certain European markets are known to have been relaxed only to be rigorously enforced later when supplies became more plentiful and prices were relatively lower.

Administrative Protectionism

Accompanying the relative decline of tariffs and other direct forms of protectionism during the past forty years has been the dramatic rise of an indirect, or administrative, protectionism, most of which has had a symbiotic relationship with nontariff laws and regulations. The passing of power from legislative to administrative forms of government has resulted in increasing opportunism in policy making and interpretation and has rendered it necessary for decisions to be made more quickly and in more complicated detail. One has but to observe the decision-making possibilities in the Foreign Agricultural Service (FAS) of the U.S. Department of Agriculture (USDA) or in the European Common Agricultural Policy (CAP) at Brussels to appreciate the strategic position of certain adminis-

trators. In such situations, what pressures are actually effective in making and interpreting policy? Who has the ear of those who must take action? Whose judgment and advice is used? How far are decisions based upon practical considerations concerning which responsible officials have, if not full, at least the best, information available? Do they tend to consult experts who must almost necessarily be individuals with a direct personal interest in the decision to be taken? Are the administrators more or less open to the pressure of vested interests when their actions are further removed from public review (Condliffe, p. 31)?

These questions defy clear and decisive answers but certain generalizations can be made. In the first place, however high-minded and able the administrators who conduct day-to-day policy, there is a real danger in their progressive withdrawal from direct and detailed public criticism and responsibility. Those who would question this should go into the burrows of officialdom and try to pinpoint who really is responsible for decisions and their implementation with respect to the United States under Section 22 of the Agricultural Adjustment Act, in the compensatory payments on grain in the European Economic Community (EEC), and so on. The real danger is not so much graft and corruption, but, more subtly, in the concentration of power among those who are not subject to public action and whose cumulative errors in judgment are not brought into immediate account.

Another fact appears clear from recent experience. Concentration of policy-making power among administrators puts a premium upon organized pressures from directly interested groups and lessens the consideration likely to be given to the general public interest, particularly unorganized consumer interest. This, of course, is not unique to agriculture. In the case of agriculture, the result is that government policy and regulation in the area of nontariff barriers has been dominated historically by organized producers. Agricultural marketing schemes, export programs, and regulatory activities are in many cases directly accountable to farming interests. The various international commodity control programs set up to regulate production, trade, and prices are primarily designed to protect the financial structure of existing investments, even at the expense of new investment opportunities in areas of developing production.

Administrative devices used to restrict trade range from the imposition of fees and the selective issuing of licenses to the use of regulatory measures such as veterinary, health, quarantine, and similar restrictions imposed for specific purposes, or merely to the literal application of wide powers taken by governments to ensure adequate inspection, classification, statistical recording, allocation of quotas, or valuation of imports. Since there is a well recognized procedure of judicial interpretation and appeal in most countries, estimates of the effectiveness of these laws and regulations ought to be made by investigation of the actual administrative practices followed in each country rather than by analyses of the powers granted by legislation.

Suffice it to say that in recent years in the case of quantitative restrictions—quotas, license fees, exchange controls, and the like—it has been possible to pinpoint rapidly discriminatory practices, whereas the interpretative norms for certain regulatory activities are difficult to discover. As one European agricultural official reported, "Honestly, it depends on the price of ___ as to how rigorously I apply this particular regulation." In sum, the administrative aspect of protection is many times more important than the essence of law and regulations (Curzon and Curzon, pp. 26–33).

Issues in Theory and Measurement

As has been implied already, measurement of nontariff protection is a difficult undertaking—much more difficult than that of tariffs which are not only more identifiable but also more quantifiable. What follows is an attempt to demonstrate briefly that even though there are difficulties in theory and measurement, protection through the use of nontariff agricultural barriers is still recognizable, and deliberate discrimination against foreign production is still identifiable. Admittedly, however, satisfying the economist's criteria with respect to welfare in every case is almost a hopeless task (Corden 1971, 1974). Theoretical treatments of special cases of less than completely free trade based on the assumed existence of market or infant industry distortions, or on cases which assume different economic objectives, have been developed in recent literature (Bhagwati, Johnson).

Perhaps a warning should be given to those who deem all government restrictions on trade

as "bad." All so-called nontariff barriers are not evil, nor are all of them equivalent to tariffs in their effects. Since the economist's case against nontariff barriers can be overstated and confusing as to assessment and remedy, several clarifying points need to be made.

First, as we have pointed out already, there are literally thousands of national laws and regulations that affect the movement of agricultural products across international boundaries. Many of these national—and even supranational—laws and regulations are trade-facilitating and trade-enhancing, being necessary to the commerce of a modern society. Indeed, the fivefold growth in trade volume since World War II in an increasingly economically complex and technological world would hardly have been possible without regulations, standards, and public direction. There is a whole range of national statutes and regulations designed not only in the public interest of particular nations but also in the interest of the world. The prohibition of foods unfit for consumption and of articles dangerous to the health of human beings, animals, or plant life fall into this category. The enforcement of these laws and regulations can lead to confusing and misleading assessments about economic effects of nontariff barriers.

It is difficult to form a sound judgment concerning the degree to which a country makes unfair use of biological precautions and marketing standards which are legitimate in certain circumstances. For example, as originally provided in the U.S. Tariff Act of 1930, the legislation enacted to check the spread of rinderpest or foot and mouth disease was, no doubt, largely protective in intent (Bidwell, p. 211–12).

The demand for new, processed agricultural products in industrialized countries is diversified and tends to change continuously. If conditions permit, developing countries can take advantage of the existence of these expanding outlets by resorting to appropriate marketing strategies, e.g., new products. Much is being done by *Codex Alimentarius* to make uniform food and other standards preparatory to international shipments (FAO).

A second clarifying point on economic assessment of laws and regulations relates to discriminatory measures which governments take that, judged by conventional economic criteria, might worsen welfare of the country imposing the policy but improve that of the rest of the world (Hindley). With some nontariff distortions, such as export subsidies and certain quota systems in which quota rights are allocated to foreigners rather than to nationals, the economic case against the distortion is different than that against conventional tariffs. The reasoning by economists implies the possibility that by imposing tariffs, a nation may gain at the expense of the rest of the world, thereby reducing world income; whereas with certain nontariff instruments as cited above, even though world income still is reduced, the "rest of the world"—other than the nation imposing the distortion—gains. The changed outcome in those instances between tariff and nontariff barriers gives rise to the question: With whose welfare should international arrangements be concerned?

Obviously, the problem does not terminate simply in one of measurement of aggregate incomes between one nation, the "rest of the world," and the world. Should nations be constrained from using instruments that are consciously used to reduce the welfare of their citizens? Distributional problems within "the rest of the world"—some nations gaining, others losing—will also result from nontariff national policies, and an outcome is not determinable a priori. The point remains, in this issue, as with the issue regarding regulatory policies, that all outcomes of nontariff intervention cannot be judged "bad" on the basis of conventional resource allocation analysis.

Yet another point that needs to be clarified relates to the attributes and the role of economics as a policy science. If it might be assumed that all citizens of a country are enlightened and well informed and that a general will or purpose emerges without serious protest, one might accept the notion that political decisions, including those about nontariff protection and related policies, must embody a collective utility sufficiently large to offset the loss of private utilities they obviously occasion. James Tobin has asked why the preferences of individuals "should be worthy of respect only when they are expressed in the market, why the preferences of the very same individuals expressed politically should be regarded as distortions" (p. 11). Alternatively, Gohren Ohlin points out "anyone who is preoccupied with the prevalence of market failure in the economic process must be at least as impressed with 'market failure' in the political process" (p. 174). In short, public action cannot abolish Keynes' famed "risk, uncertainty, and ignorance" and cannot itself escape them. To postulate the rationality of

national governmental processes is to eliminate the political element of political economy and to neglect the problem of inadequate knowledge on the part of politicians and administrators. This might be more heroic than to postulate market perfection.

Ohlin, like many others, recognized that nations are bound to seek a degree of control over their economic destinies which will in some cases entail a sacrifice of conventional resource allocation, at least in the short run. Moreover, continued trade liberalization probably will force governments to seek this control in new ways. The domain of domestic distortions through development, technology, and new industrial policies and those nontariff trade barriers relating thereto are more than likely to be where government intervention will increasingly assert itself rather than trade restrictions at national borders. Comparative advantage and the traditional concept of an effective division of labor thus become more difficult to ascertain in a changing world of sophisticated protectionist instruments, which do not lend themselves easily to codification and measurement.

Finally, because the impact of nontariff barriers is difficult to quantify and measure, they do not lend themselves easily to bargaining in a multilateral context as has been the case with tariffs in previous rounds of GATT negotiations. Hindley (p. 2) speculates that the Kennedy Round was facilitated by each government's knowledge that it could, if necessary, substitute nontariff methods of protection for the explicit tariff protection it was giving up. No such facilitating reservation is possible for nontariff barriers, which probably means that future negotiations must deal with the hardest core of governmental impulses to protectionism. The economist's objective is to try to define a positive outcome which could satisfy economic criteria of welfare improvement (for our purpose, an increase in world welfare) and which would stand some chance of official acceptance. The practical objective, again, is to minimize or eliminate the political element in political economy, and to overcome the problem of inadequate knowledge of politicians and administrators.

Taxonomy of Nontariff Barriers

In recent years, there have been various attempts to identify, classify, and tabularize in some quantitative sense governmental measures which affect agricultural production, imports, and exports. The basic inventory performed by GATT (Patterson) after the Kennedy Round consisted of more than 800 items, agricultural and nonagricultural; but other agencies, such as the USDA, have done subclassificatory and identification work, as will become evident later. Not all protection techniques involve import-restricting measures. Some export-increasing and export-restricting schemes have been added to, or combined with, import nontariff interferences. In the agricultural field, the GATT classification process was not limited to measures taken at national borders, since domestic programs, most of which relate to production and supply, often have a powerful effect on possibilities of market access by foreign distributors. The items were arranged in five general categories: *Section 1.* Government participation in trade, including (*a*) production subsidies, (*b*) export subsidies, (*c*) countervailing duties, (*d*) government procurement and restrictive business and union practices, and (*e*) state-trading enterprises in market-economy countries. *Section 2.* Customs and administrative entry procedures, including (*a*) customs valuation, (*b*) antidumping practices, (*c*) customs classification, and (*d*) formalities connected with importation. *Section 3.* Industrial, health, and safety standards, and packaging, labelling, and marking regulations. *Section 4.* Specific limitations on imports and exports, including (*a*) licensing arrangements, (*b*) quantitative restrictions including embargoes, (*c*) bilateral agreements, (*d*) voluntary restraints, (*e*) motion picture restrictions, and (*f*) minimum prices on textile imports. *Section 5.* Restraints on imports and exports by the price mechanism, including (*a*) prior deposits, (*b*) administrative and statistical duties, (*c*) restrictions on foreign wines and spirits, (*d*) discriminatory taxes on motor cars, (*e*) special duties on imports, (*f*) credit restrictions for importers, (*g*) variable levies, and (*h*) border taxes.

Nontariff Barrier Classification in Selected Countries

An agricultural committee was set up in GATT after the Kennedy Round to search for mutually acceptable solutions to nontariff barriers in both agriculture and other industries. All along, agricultural problems and nontariff barriers within the agricultural sector had been underestimated by most negotiators as a

source of trade conflict. This became even more evident as each country defended special features of its agriculture in the committee discussions aimed at progress toward trade liberalization.

The GATT agricultural committee encountered many difficulties in carrying out its task. Documentation and problem identification took more than two years, during which time the basic inventory was made of measures affecting agricultural imports (including processed products) of the major trading countries. That inventory included tariffs, quantitative restrictions, variable levies and other special changes, health and sanitary regulations, and various other nontariff barriers to trade. The inventorying and cross-classification involved a vast amount of time and paperwork, as any visitor to the GATT offices can testify. The inventory is kept up-to-date and could, during the future trade negotiations, provide a concrete basis for progress in trade liberalization.

In the case of import restrictions, detailed summaries of data prepared by GATT cover those countries for which information on all types of restrictive measures are available. In the case of tariffs, the information is presented in the form of four ad valorem incidences for each country and for each Brussels Nomenclature heading. In the case of quantitative restrictions (including centralized trading), summaries indicate the type of restrictions in force. For variable levies and other special changes, summaries show for each country, and for each four figure heading, the simple and weighted averages of the incidences. In the case of health and sanitary regulations, a succinct tabulation has been constructed with extensive notes as to country and regulation.

Out of these vast and detailed summaries one is able to derive import restrictions by country and general product category. Such a classification has been prepared in the GATT for nontariff restrictions. Quantitative barriers and related licensing procedures dominate and vary from country to country. For example, in the dairy products category, only a few countries out of the many listed do not report some form of quantitative restriction or licensing. And, of these few countries, health regulations, state trading, or other nontariff barriers are reported in most. Other nontariff barriers may be generally observed by studying the summaries.

Even though no attempt is made in GATT to interpret the results of the original classifications and summaries and other such subsummaries, the reduced form of these materials assists one in appreciating the nature and location of certain import restrictions. In fact, GATT warns repeatedly of the danger of assessing degrees of protection from the "raw" classification. For example, it is often impossible to make a direct comparison between the ad valorem incidence of tariffs and variable levies. The protective effect of a tariff of 30% ad valorem is, for example, not necessarily the same as the protective effect of a variable levy with an ad valorem equivalent of 30%. In any case, a straight comparison of the ad valorem equivalents of tariffs and levies in various countries is not significant, because the levy is usually the only protective device used at the frontier, whereas tariffs are often reinforced by quantitative restrictions.

This fact is brought out in GATT tabulations, which also deal with quantitative restrictions. Another point to be borne in mind is that the type of quantitative restriction and variable levy used in different countries varies considerably. In practice, levies are varied frequently, in some cases, and effectively equalize internal and world market prices. The fact that two types of levy have the same ad valorem incidence would not necessarily mean that they have the same effect.

Table 1 demonstrates a way of presenting the extent and general nature of nontariff barriers applying to imports of agricultural and other primary commodities for the leading industrial countries. This table, adapted from the United Nations Conference on Trade and Development (UNCTAD) material, involves not only an explanation of the general nature of the restraint at country borders but also certain types of explicit government intervention in domestic markets.

These summaries and similar materials, along with research being done in individual countries, assist greatly in understanding the nature of the problem and will benefit those who are dealing with removal of restrictions and with trade liberalization. The USDA Foreign Agricultural Service, for example, published a series of circulars in 1972–73 on its trade with selected European countries and Japan. These circulars dealt with import control devices by country and recent changes in nontariff barriers and tariffs. They also tabulated U.S. exports to the countries in question for a seven-year period, and the type of non-

Table 1. Agricultural Commodities: Nontariff Barriers to Imports into Major Industrial Countries, 1971

	European Economic Community		Japan		United Kingdom		United States	
Commodities	A	B	A	B	A	B	A	B
Food, beverages and tobacco:								
Wheat	CMA	Se	QM	S	—	Sd	Q	Se
Rice	CMA	Se	QM	S	—	—	—	Se
Barley	CMA	Se	QM	S	—	Sd	—	Se
Maize	CMA	Se	—	—	—	—	—	Se
Sugar	CMA	Se	—	S	Q	S	Q	S
Beef and veal	CMA	Se	Q	—	—	Sd	Q[a]	—
Pigmeat	CMA	Se	M	S	q	Sd	—	—
Mutton and lamb	q[b]m[b]	—	—	—	—	Sd	Q[a]	—
Poultry	CMA	Se	—	—	—	—	—	—
Eggs	CMA	Se	—	Q	—	Sd	—	—
Butter and milk	CMA	Se	QM	Sd	Q	S	Q	Se
Fish	CMA	—	q	—	—	S	—	—
Citrus	CMA	Se	q	—	q	—	—	—
Bananas	Q[b]	—	—	—	Q	—	—	—
Wine	CMA	S	—	—	—	—	—	—
Tobacco	CMA m[b]	Se	M	S	—	—	—	Se
Oilseeds, oils and fats:								
Soybeans and oil	—	—	—	Sd	—	—	—	Se
Groundnuts and oil	—	—	—	—	—	—	q	Se
Cottonseed and oil	—	—	—	—	—	—	—	S
Rapeseed and oil	CMA	S	—	Sd	—	—	—	—
Linseed and oil	CMA	S	—	—	—	—	—	S
Sunflower seed and oil	CMA	S	—	—	—	—	—	—
Olive oil	CMA	Sd	—	—	—	—	—	—
Castor seed and oil	—	—	—	—	—	—	—	S
Fish meal	—	—	q	—	—	—	—	—
Agricultural raw materials:								
Cotton	—	—	—	—	—	—	Q	Se
Wool	—	—	—	—	—	S	—	Sd
Jute bagging	q[b]	—	—	—	q	—	—	—

Sources: UNCTAD. *Commodity Problems and Policies.* TD/115, 22 Jan. 1972, table A-1; EEC Commission. *Fourth General Report on the Activities of the Communities, 1970.* Brussels, Feb. 1971; Great Britain, Ministry of Agriculture, Fisheries and Food. *Annual Review and Determination of Guarantees 1971* (Cmnd. 4623), H.M.S.O., Mar. 1971; United States, Office of the President, Commission on International Trade and Investment Policy. *United States International Economic Policy in an Interdependent World: Report to the President,* Washington, D.C., July 1971. GATT documents prepared in connection with the work of the Agriculture Committee and the Committee on Trade and Development.

Note: Column A shows the general nature of the restraint at the frontier. A small letter indicates that the measure is applicable to only part of the item in question: M, m—state trading or trading by an authorized monopoly; Q, q—quota restrictions; CMA—commodity falling under Common Market arrangements. Column B indicates the general nature of explicit official intervention on domestic markets, not including direct or indirect subsidies of inputs of the primary sector or fiscal privileges accorded to that sector: Q—organization of the domestic market without official price fixation; S—price supported or production subsidy paid; Sd—price guaranteed by deficiency payment; Se—support accompanied by provision for export subsidy.

[a] Contingency quotas on beef and veal and mutton authorized by legislation (not so far applied), accompanied by restraints by supplying countries.

[b] Certain member states only.

tariff barriers of those countries by commodity description and tariff number. Similar information is found in a report to the subcommittee on International Trade of the U.S. Senate Committee on Finance (see U.S. Tariff Commission).

Application and Impingement of Nontariff Barriers

A noticeable aspect in the current discussion on nontariff barriers in agricultural trade is the lack of "hard" evidence about the manner in

which the statutory and regulatory restrictions are applied, the degree to which trade is impeded by their application, and the magnitude of protection to particular commodities or commodity groups afforded by them. The GATT work of inventorying and classification is clearly preparatory to the next stage of exploring possible ways in which barriers arising from agricultural measures could be dealt with. That stage has been under way in GATT for some time but clearly does not involve measurement and commitment on the part of participatory governments.

Another striking aspect about the nontariff deliberations (as well as those dealing with customs duties) is that such evidence as exists pertains to violations or infringements in developed, as opposed to developing, countries (Balassa). This asymmetry, of course, is understandable due to the magnitude and importance of trade in the developed countries and the dominating nature of that trade on economic growth and welfare in developing countries.

Tables 2 and 3 are illustrative of these aspects of the nontariff barrier. UNCTAD, which generated the information for these tables, has not taken the additional step of calculating scientifically the effective rate of protection in various countries, either for tariffs or nontariff measures. Table 2 shows that the use of nontariff barriers varies widely among developed countries, reflecting not only the competitive position of the countries involved in world trade but also the degree of reliance in the various countries on regulatory mechanisms in the trade process. France, for example, clearly uses nontariff techniques to regulate its international trade to a greater degree than Canada or Australia. Again, one must be warned that summaries and frequency charts are not measures of effective protection. They are indicators, however, of the potential harassing—as well as restrictive—nature of the nontariff measures in countries where they exist.

Table 3 gives a general idea of the "visibility" of the relative impact of nontariff barriers on developing countries after tariffs had been reduced on certain processed agricultural products. Processed meats, processed cereal products, fruits, and vegetables have a high frequency of restriction, and in the case of meats, fruits, and vegetables, high trade values are involved. Types of nontariff restrictions covered by these tabulations are all those described earlier in this paper, the most frequently used of which are import quotas and licensing.

Fortunately, the international organizations

Table 2. Frequency of Import Restrictions Applied in Individual Developed Market Economy Countries on Products of Export Interest to Developing Countries

Importing Country	Number of Products Affected by the Restrictions	Frequency of Restrictions Applied[a]
France	88	140
Federal Republic of Germany	40	54
Italy	33	38
Benelux	25	27
Denmark	26	29
Finland	26	33
Austria	22	37
Norway	20	26
United Kingdom	17	19
Sweden	17	17
Switzerland	13	24
Japan	34	34
Ireland	21	21
United States	15	17
Canada	11	11
Australia	4	4
Total products affected	130[b]	531

Source: UNCTAD, *Commodity Problems and Policies*. TD/115, 22 Jan. 1972, table A-1.

[a] Each particular type of restriction is counted once for each country applying it to a particular product or group of products; more than one type of restriction may be applied to a product in a given country.

[b] About 50% of these products are affected by restrictions applied in more than one country.

Table 3. Frequency of Nontariff Import Restrictions Applied by Product Group

Product Group	Imports by Developed Market Economy Countries, 1968[a]	Frequency of Restrictions[b]
BTN Chapters 1–24	($ millions)	(%)
Processed meat products	114.6	21.4
Processed cereal products and preparations	16.4	24.6
Processed fruit products	118.7	22.5
Processed vegetable products and edible preparations	61.5	12.5
Sugar, sugar derivatives, and chocolates	4.4	7.9
Beverages and alcohols	96.0	7.9
Tobacco manufactures	2.1	1.8
Other products	0.3	1.4
Total	414.1	100.0

Source: UNCTAD. "Program for the Liberalization of Quantitative Restrictions and Other Nontariff Barriers in Developed Countries on Products of Export Interest to Developing Countries." TD/120/Supp. 1, 31 Jan. 1972.
[a] Based on those countries which maintained restrictions recorded in 1971.
[b] Each particular type of restriction is counted once for each country applying it to a particular product or group of products; more than one type of restriction may be applied to a product in a given country.

are all becoming more interested and involved in the measurement of agricultural protection by measures taken at the border of a country and by those domestic measures a country uses which restrict the free flow of trade (Balassa).

The Food and Agriculture Organization (FAO) and the Organization for Economic Cooperation and Development (OECD), in addition to GATT and UNCTAD, are currently researching the techniques of agricultural protection. These efforts, coupled with a large number of national and private studies, should assure the world of more and better information on the subject than has existed in the past.

State Trading as a Nontariff Barrier

The large grain purchases by the Soviet Union in 1972, the partial cancellation of U.S. grain sales to the Soviet Union in 1974, and the increasing importance of the People's Republic of China as an agricultural importer have focused attention on appropriate methods of dealing with exports to and imports from planned economies. Problems involved in exporting agricultural products to them should not be minimized if, as many experts believe, those countries continue to purchase large quantities of grain from the market economies.

Trade distortions created by state trading and related monopoly-monopsony conditions of demand and supply in world trade of agricultural products can be solved partially through better information, especially about total world supplies. Improved information and the rational decisions that might flow therefrom are to be preferred to the confrontation of buyers and sellers acting in ignorance. The alternative of shared information on matters relevant to potential imports and exports is discussed in a recent USDA/ERS publication. This general alternative was further explored in the Rome World Food Conference in late 1974.

Because of the tendency of modern economies toward control brought about by the concentration of decision-making power in administrative machinery, there is danger of essentially economic decisions turning more toward purely political considerations. Market factors in such cases become dominated by extra-market factors. And, nontariff barriers in their most complex, regulatory forms exist and flourish in the guessing game of administrative bureaucracies.

Negotiating Nontariff Trade Barriers

It is appropriate to conclude by outlining and briefly commenting on some of the crucial options and courses to be considered when dealing with nontariff and agricultural restrictions in the context of international trade negotiations. This commentary, though constructed

during the Tokyo Round negotiations, is not written specific to those negotiations. The issues raised are generic in nature and apply to current as well as future negotiating fora. Indeed, they might well have been relevant to the politics and events of the Tokyo Round, but are no less relevant for future consideration.

The Tokyo Round talks started in September 1973 and were to have concluded by the end of 1975. They were still in progress in 1978. Having originally been compressed into a tight time framework, there was a limit to issues that might be considered. Two major issues in this round were how to negotiate with the European Community, and whether the developing countries and Eastern Europe were to be real participants or on the sidelines during GATT negotiations among rich countries.

Foremost to be decided now is whether agricultural trade negotiations should be carried on primarily under the GATT or whether there should be supplemental institutions or arrangements for bargaining. Though there has been criticism of GATT's accomplishments on nontariff and agricultural barriers during the Dillon and Kennedy Rounds, demands for abandoning the GATT have not yet been taken seriously.

Since all multilateral trade negotiations take place predominantly under GATT auspices, is it feasible to conduct those of the agricultural and industrial sectors jointly? There is considerable disagreement on this point. Many interest groups and experts, especially those related to agriculture, support the concept of a joint negotiation process and believe that the failure to adhere to it during the Kennedy Round led to many problems. In other words, they feel agriculture must be treated in the same manner as other sectors. Others feel equally strong about separate negotiations on agricultural trade issues and say that the existing rules of GATT as they apply to agriculture must be modified so as to get at the principal obstacle to international trade liberalization; namely, domestic farm policies. In this latter view, agriculture is different and must be treated differently.

A third major issue is the basis for negotiation. There seems to be general agreement among the experts that some method must be devised to measure the degree of protection—to quantify it in money terms—that nations give to their agricultural sector through domestic policies. Also, this economic calculation, though expensive and time-consuming, must precede any realistic, politically determined codes of conduct that might cover restrictive trade devices.

A most critical issue is codes of conduct, including rules of competition. Governments must be convinced that many of their present nontariff barriers and farm policies are of little value, although enormously costly, if there is to be a basis for successful negotiations on agricultural restrictions. In this regard, little can be gained by having trade barriers themselves the main topic of discussion during the negotiations. In such an atmosphere, as witnessed in the GATT and, before that, in the Reciprocal Trade Agreement Acts of the United States, it has been difficult for a country to find an adequate *quid,* in political terms, for the *quo* given up when it renounced its protective devices. Prospective poor results in the swapping of trade concessions, therefore, may be an argument against holding agricultural and nontariff negotiations separately.

The concept of harmonization of policies is likely to be more successful when countries and industries can agree on issues which can be supported by treaty-bound agreements. This might be possible in the broad areas of health and sanitary regulations, grades, standards, and food codes, and even in administrative interpretation of legislative intent.

Ultimately, the fundamental issue is: how do governments obtain the necessary authority to negotiate meaningfully on such questions as nontariff agricultural trade barriers and related matters? As has been strongly noted in this study, agricultural protection has been associated for at least two centuries with social and philosophical issues related to agrarian life and its values. In addition to this, nontariff barriers touch not only on economic policies but in many cases relate to vast administrative bureaucracies in which public employment is an issue. Here the outcome of trade negotiation could, *ex ante,* be affected by some perceived effect it might have on the authoritarian mechanism.

In sum, nontariff and other agricultural trade barriers are tied up in all kinds of domestic laws, rules, and regulations managed by many different parts of each government. In the United States, for example, there is much congressional resistance to giving the executive branch a blank check; yet, the executive branch cannot effectively negotiate without

some kind of mandate. Within the executive branch there is competition among the departments as to who will wield the power; hence the administrative bureaucracies within the departments vie keenly with each other for that power.

Section 102, Title I, of the U.S. Trade Act of 1974 deals specifically with negotiating authority relative to nontariff barriers and other distortions of trade. The president was given the authority over a five-year period to negotiate trade agreements which would harmonize, reduce, or eliminate nontariff barriers or other distortions. Before such agreements can be effectuated, however, the president must go through considerable consultation with congressional committees before entering the agreements, and he must follow strict procedures about publishing the agreements and stating how they serve the interests of the United States. It is obvious that the Congress desired assurance that the executive branch and the administrative bureaucracies would not have sole and final authority to deal with the nontariff barrier question and other vital trade matters.

Without going into further detail about the Trade Act, it should be pointed out that the negotiators in Geneva met in the Tokyo Round under circumstances which were quite different than those of the past. That is, one of the principal concerns in the past was access to markets by suppliers of agricultural products and raw materials. Today, circumstances have changed; that is, developed countries are concerned over gaining access to supplies of energy and raw materials. Many of these materials are controlled by developing countries which are increasingly forming supply cartels to promote their own interests. This is not to say that traditional types of import barriers will not exist in the future. There exists, however, a somewhat different atmosphere than that of the 1950s and 1960s when the principal concern was access to markets by large suppliers of agricultural commodities and raw materials that were in great surplus.

In the final analysis, patience may be the most important ingredient in the negotiating process. Because of the complexity of the issues in commercial policy, including nontariff barriers, agricultural protection, and others, it is likely to take several years of work to obtain much progress. Perhaps during this time it will be possible to conduct the necessary studies on levels and degrees of protection which almost everyone deems essential for a positive outcome. The length and complexity of the negotiations must be recognized, and time must be allowed for interaction between governments and their parliaments, as well as among governments themselves.

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Retail and Wholesale Demand and Marketing Order Policy for Fresh Navel Oranges

Glenn Nelson and Tom H. Robinson

The federal marketing order for fresh navel oranges appears to have been administered in early 1974 in a manner which restricted supplies to consumers, raised retail prices, and lowered total receipts of growers and packers. An examination of historical data and econometrically estimated parameters in wholesale and retail demand equations supports these conclusions. These concerns were central to a heated debate between the Cost of Living Council and the Navel Orange Administrative Committee.

Key words: demand, discrimination, marketing order, oranges, policy.

The nature of the demand for fresh navel oranges was the subject of considerable controversy in early 1974. Navel oranges are marketed under the provisions of a federal marketing order authorized by the Agricultural Marketing Agreement Act of 1937, as amended. Fresh shipments of oranges to domestic and Canadian markets are controlled by means of prorates on a weekly basis. In early 1974 the Navel Orange Administrative Committee (NOAC), U.S. Department of Agricultural (USDA), Cost of Living Council (CLC), and elected officials became embroiled in a heated debate over the setting of the total permissible weekly shipments.

The CLC became concerned when, despite a projected increase of 14% in 1973–74 navel orange production, prorates were below 1972–73 levels and prices were above a year earlier. The CLC concluded that the NOAC was acting to enhance the price of fresh shipments by restricting the amounts reaching the market. Acting through the CLC Food Committee chaired by George P. Shultz, secretary of the treasury, the secretary of agriculture was requested to raise the weekly prorates above the shipping schedule proposed by the NOAC. USDA and NOAC resisted, but prorates moved above year earlier levels in the last week of January. Fresh market shipments increased in February and March and prices declined, after a short lag in some cases. Orange growers were angry and continued to seek lower prorates.

On 28 March representatives of growers, retailers, USDA, Department of Justice (to ensure that antitrust laws were not violated), and CLC met at the invitation of CLC. CLC urged retailers to feature navel oranges so consumers would be aware of the large supply and reasonable prices; growers were urged to continue to ship all fruit of adequate quality to the fresh market. The position of John T. Dunlop, director of CLC, and Kenneth J. Fedor, director of the Office of Food, CLC, as reported in the *New York Times*, was: "increased shipments at lower prices might mean lower total revenues for navel orange growers, who are concentrated in California and Arizona. But, . . . supermarket "specials"—combinations of price cuts and heavy advertising—could generate extra volume and revenues" (Cowan, p. 44).

The uproar from growers continued. They successfully marshalled influential congressional support for their position. In early April, CLC lost the support of the White House. The lower prorates recommended by NOAC were approved by USDA. Fresh ship-

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ments declined and prices rose. The NOAC position is stated clearly in its 1973–74 *Annual Report:*

> Interference with the Marketing Order by the Cost of Living Council caused needless loss to Navel orange growers estimated by some industry sources to be 3 to 4 million dollars. . . .
>
> The Cost of Living Council's interference began when it forced its influence on the Secretary, and in 10 of 12 consecutive weeks beginning the week ending January 10, compelled weekly allotments higher than recommended by the Committee with little or no regard for consequences to the industry. . . .
>
> The chaos and market instability caused by actions of the Council resulted in average f.o.b. prices dropping from about \$3.86 a carton to \$3.25 a carton during the 10-week period. With excellent fruit quality and favorable marketing conditions then existing, such purposeless price deterioration would not have occurred had the Committee been permitted to fulfill its responsibility and the industry been able to market the oranges under orderly marketing conditions. Ironically, trade surveys during the period revealed practically no reduction in retail prices of Navel oranges—a fact that belies the justification given by the Cost of Living Council for its unconscionable intervention in the industry's business (p. 4).

The purpose of this article is to examine the merits of the opposing positions. The critical economic factors are the elasticity of wholesale demand and the behavior of the wholesale-retail price spread as wholesale prices fall. A model of the retail and wholesale demand for fresh navel oranges is specified and estimated in order to ascertain the underlying economic behavior.

Model and Parameter Estimates

Consumer demand is specified as

$$PR = f(QN, QF, QA, QG, M), \tag{1}$$

where PR is real retail price (1967 dollars), QN is per capita quantity of fresh navel oranges; QF, per capita quantity of other fresh oranges; QA, per capita quantity of apples; QG, per capita quantity of fresh grapefruit; and M, a monthly binary variable included to account for systematic seasonal variation in product quality and consumer tastes. Monthly supply of fresh navel oranges is assumed to be predetermined by natural processes and the decisions of the NOAC.

Wholesale demand is specified as

$$PW = g(PR, TQN, W), \tag{2}$$

where PW is real wholesale price (1967 dollars), PR is real retail price as in (1), TQN is total quantity of navel oranges, and W is the real wage (1967 dollars) of grocery employees. Note that QN equals TQN divided by population.

The data include the months of December through May in the 1967–68 through 1975–76 seasons. The retail price of fresh navel oranges is collected by the Bureau of Labor Statistics (BLS) and reported by USDA on a dollars per carton basis. The quantity data for shipments of fresh oranges and grapefruit and the wholesale price of navel oranges are found in the reports of the NOAC and the Growers Administrative Committee of the Florida Citrus Industry. The weekly quantity data were first aggregated into figures on million cartons per month, and then the actual monthly totals were converted to a standard thirty-day month by multiplying by the appropriate fraction, e.g., 30/28 or 30/31. The monthly wholesale price in dollars per carton was computed from a weighted average of weekly f.o.b. shipping point prices.

The quantity of apples is the U.S. commercial crop in billion pounds as reported by USDA. The annual apple crop figure is used for each monthly observation. While crude, this approximation is deemed adequate for the six-month period, especially in the presence of the monthly binary variables. Wage is measured by the monthly BLS reports on the average hourly earnings of employees of grocery, meat, and vegetable stores. The consumer price index (1974 = 100) was used to convert all prices and wages to real values. Population refers to total resident U.S. population. Finally, the February 1972 observation was eliminated from the analysis because of the very high retail price recorded in Chicago, which was inconsistent with observations on all other variables including retail prices in other cities, and which could not be explained by any known factor.

The model represented by equations (1) and (2) was applied to two major retail markets, New York and Chicago, and a common wholesale market. The results are displayed in table 1. Several pre-tests with respect to included variables and functional form were performed on the 1967–68 through 1974–75 data. After these were complete and the functional forms in table 1 were hypothesized, the regression analysis was extended through 1975–76 as a test of structural validity (Chow). The com-

Table 1. Retail and Wholesale Demand Equations for Fresh Navel Oranges in New York, Chicago, and Shipping Points

			Wholesale: Shipping Point Destined for:			
	Retail[b]		Structural[b]		Restricted Reduced Form[c]	
Explanatory Variables[a]	New York	Chicago	New York	Chicago	New York	Chicago
Quantity of navels						
QN_t	−.179	−.095	—	—	—	—
	(.264)[d]	(.259)				
QN_{t-1}	−.580	−.296	—	—	—	—
	(.299)	(.286)				
QN_{t-2}	−.232	−.372	—	—	—	—
	(.279)	(.272)				
TQN_t	—	—	−.234	−.195	−.266	−.215
			(.099)	(.121)		
$(TQN)_t^2$	—	—	.0239	.0183	.0239	.0183
			(.0127)	(.0158)		
TQN_{t-1}	—	—	—	—	−.103	−.064
TQN_{t-2}	—	—	—	—	−.041	−.080
Other fresh oranges						
QF_t	.292	.314	—	—	.110	.143
	(.333)	(.320)				
QF_{t-1}	.086	.447	—	—	.032	.203
	(.354)	(.345)				
QF_{t-2}	−.445	−.685	—	—	−.167	−.311
	(.403)	(.393)				
Other substitutes						
QA_t	−1.309	−.936	—	—	−.491	−.426
	(.355)	(.342)				
QG_t	−.728	−.318	—	—	−.273	−.144
	(.188)	(.183)				
Monthly binaries						
DEC_t	−1.802	−1.893	—	—	−.676	−.861
	(.821)	(.812)				
JAN_t	−.543	−.993	—	—	−.204	−.452
	(.600)	(.587)				
MAR_t	−.262	−.570	—	—	−.098	−.259
	(.506)	(.489)				
APR_t	−.657	−.763	—	—	−.247	−.347
	(.445)	(.431)				
MAY_t	−1.575	−1.246	—	—	−.591	−.567
	(.520)	(.507)				
Grocery wages						
W_t	—	—	−1.757	−2.171	−1.757	−2.171
			(.593)	(.647)		
Navel retail price						
PR_t	—	—	.375	.455	—	—
			(.068)	(.647)		
Intercept	16.279	12.647	4.653	5.369	10.758	11.123
	(1.531)	(1.494)	(1.823)	(1.911)		
F-statistic	13.5	5.9	38.4	24.3	—	—
	[13,39][e]	[13,39]	[4,48]	[4,48]		
R^2	.82	.66	.76[f]	.67[f]	—	—

[a] See text for detailed definitions.
[b] Estimated by three-stage-least squares.
[c] Constructed by substituting the retail equation into the structural wholesale equation. A population figure of 210.8 million (February 1974) was used in adjusting the coefficients of QN from a per capita to a total quantity basis.
[d] The figures in parentheses are the appropriate standard errors (adjusted for degrees of freedom).
[e] The figures in brackets are the degrees of freedom for the (asymptotic) F-statistic.
[f] Based upon residuals computed from the original observations on the explanatory variables.

puted (asymptotic) F statistics for the equations in columns (1) through (4) of table 1 were 1.2, 0.7, 1.5, and 0.4, respectively, which are encouraging.

Interpretation of Results

The total retail price flexibilities for New York and Chicago, evaluated at the mean, are $-.26$ and $-.22$, respectively. As per capita shipments vary seasonally from low to high levels, the flexibilities vary in a range of about $-.13$ to $-.45$. The statistical significance of the coefficients of the individual quantity variables is generally low and some coefficients possess unexpected signs, as is common in lagged formulations due to multicollinearity problems. While the individual coefficients are unbiased estimates of the interim impacts in each month, conclusions based upon the total influence of a variable entering with several lags (i.e., the sum of the individual coefficients) have a stronger basis than those based upon individual coefficients of lagged variables. The retail demand for navel oranges alone is considerably more elastic than the demand for all fresh oranges, as is expected. Matthews, Womack, and Huang estimated a price flexibility for all fresh oranges of $-.83$ from annual data. George and King (p. 48) found a retail price elasticity of $-.66$ for all fresh oranges.

The fresh fruit substitutes of apples and grapefruit exhibit considerably more statistical significance than shown in prior studies. Rausser (p. 730) experimented with these and other fresh fruit substitutes but deleted them from his final model estimated from 1954–67 data due to insignificance and other undesirable features. Matthews, Womack, and Huang included apples and bananas with encouraging but less statistically significant results.

The failure of orange concentrate product prices to enter into retail demand is consistent with most, but not all, other studies. Matthews, Womack, and Huang did not include orange concentrate prices. Prato, as reported by Rausser (p. 10), found that the demands for fresh oranges and concentrate are independent in the winter season that is the subject of this analysis. A series of studies at the University of Florida of the demand for processed orange products has not included fresh oranges as a substitute (Myers and Liverpool, Ward, and references cited therein). Rausser (p. 730) included frozen orange concentrate and chilled orange juice in his study of the demand for fresh oranges.

Income was deleted from the retail demand equation despite the strong theoretical basis because of the unexpected, negative sign. The omission of income is consistent with Rausser's model. However, George and King found a substantial income response for oranges. Matthews, Womack, and Huang included income, but they also included a time trend. The negative impact of the time trend nearly neutralizes the positive impact of income. Since the two variables are highly correlated and not statistically significant, the results may be spurious.

The monthly binary variables were included to account for systematic seasonal influences not contained in other explanatory variables. The smooth pattern assumed by the coefficients is a reflection of product quality reaching a peak in midseason.

The structural wholesale demand equations are similar to the function estimated by Matthews, Womack, and Huang. The results are also similar, with increased quantity showing a negative impact on wholesale prices over the full range in Matthews, Womack, and Huang, and over much of the relevant range in this study. The restricted reduced form equations, also shown in table 1, are useful for further analysis of wholesale prices. (The restricted reduced form estimates differ from direct estimates of the reduced form due to the inclusion of more structural information in the former.) The total wholesale price flexibility, evaluated at the mean, is $-.32$ in both restricted reduced form equations. As discussed for retail demand, the seasonal variation of quantities yields a variation of flexibilities over a range of about $-.1$ to $-.45$. These estimates exhibit the same seasonal pattern as found by Rausser (p. 792), but his flexibilities tend to be about double these estimates in absolute value.

The price impact multipliers associated with changes in fresh navel shipments are displayed in table 2. The larger total multiplier for the New York retail price as compared to the Chicago retail price may be partially a result of New York prices averaging about 11% higher than Chicago prices. The total multipliers for the wholesale price developed from the two models are very similar, which, of course, is reassuring. While the distribution of the interim multipliers does vary between New

York and Chicago, the maximum price impact of an increase in shipments consistently occurs in the second or third ensuing month rather than the current month.

The results in table 2 contrast sharply with those of Heien (also see U.S. Council on Wage and Price Stability) for all fresh oranges. Heien regresses retail prices on a distributed lag of wholesale prices and wage rates in a "price equation." His conclusion is that a 1.0% change in wholesale price is associated with a 0.4% change in retail price and that the maximum impact of wholesale price on retail price occurs in the current month (U.S. Council on Wage and Price Stability, p. 33). Since retail and wholesale prices are both endogenous in the model presented in this paper, an expression describing the elasticity of retail prices with respect to wholesale prices has no analytic content beyond its value as a descriptive statistic. However, comparisons among total multipliers such as those in table 2 are useful and analytically sound. Comparing the total multipliers with the sample means for prices, we find that the percentage change in retail prices in response to a change in shipments equals about 80-95% of the percentage change in wholesale prices. (The total multipliers as a percentage of the sample mean prices are: New York retail, 6.2%; Chicago retail, 5.4%; wholesale based upon New York, 6.6%; and wholesale based upon Chicago, 6.8%.) Furthermore, while the interim multipliers for retail and wholesale prices show similar distributions, this study makes it clear that both prices lag underlying causal shifters by two or three months. Thus, the structural approach followed in this paper that systematically accounts for simultaneity and exogenous factors

Table 2. Price Impacts of a One Million Carton Increase in Fresh Navel Shipments

Month	Retail Price New York	Retail Price Chicago	Wholesale Price Based upon New York	Wholesale Price Based upon Chicago
	1967¢/carton			
1	−8.6	−4.6	−3.6	−4.0
2	−28.0	−14.3	−10.3	−6.4
3	−11.2	−17.9	−4.1	−8.0
Total	−47.8	−36.8	−18.1[a]	−18.4

Note: Fresh navel shipments are assumed to change from their mean value over the sample period, 4.3 million cartons, to 5.3 million cartons. Population is assumed to be 207.5 million, the actual February 1972 figure which is the approximate mid-point of the sample period. Price impacts are calculated from table 1.
[a] Total differs from the sum of the components due to rounding.

yields quite different results than the simpler theory and "common sense" approach of Heien (p. 2).

Prior to using the model to analyze the controversy between NOAC and CLC in early 1974, the ability of the model to explain the period must be examined. Comparisons of actual and predicted retail and wholesale price changes are presented in figures 1 and 2, respectively. The retail price equation for New York overestimates the decline in prices as fresh shipments rose, but the equation does catch the turning point. While merely conjecture, the unexpected strength of prices might have been a reflection of unusual stimulation of demand through extensive advertising in response to CLC jawboning. The retail price equation for Chicago gives a better representation of actual changes in prices, but also overestimates the April low point. (The paper by Hartley, noted by an anonymous reviewer, offers an interesting approach for investigation of whether retail prices are "sticky.") The

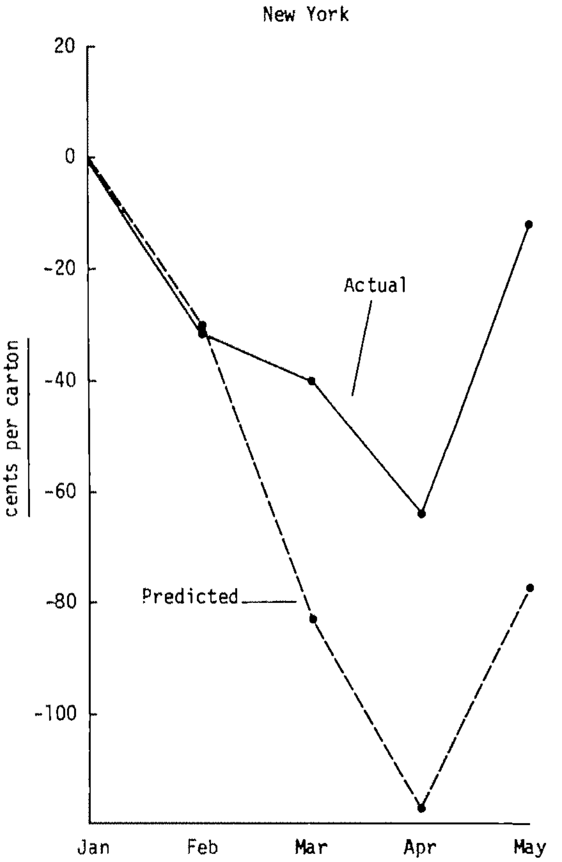

Figure 1a. Actual and predicted retail price changes from a January base, January-May 1974

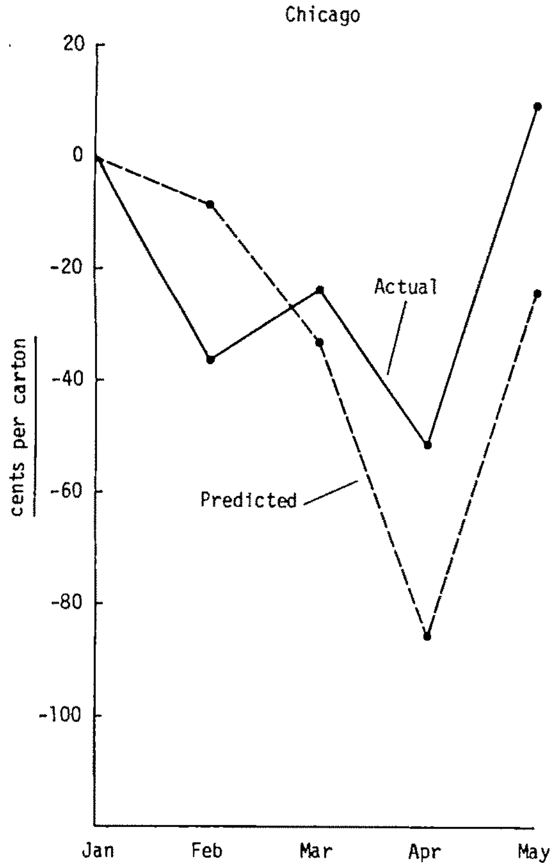

Figure 1b. Actual and predicted retail price changes from a January base, January-May 1974

predictions of wholesale price changes are less satisfactory than the retail estimates. The models predict a trough in April and a marked rise in May. Actual wholesale price reached a low point in March and declined slightly from April to May. The large decline observed from February to March may be a reflection of a major strike by independent truckers in February as they were subjected to a financial squeeze growing out of the OPEC instigated petroleum crisis. The resulting strain on the transportation system and abrupt shift in trucking rates may have appeared with a brief lag. Ending on a more positive note, the wholesale models accurately predict a small rise in February prices as shipments rose followed by lower prices in March and April as higher levels of shipments were maintained.

Conclusions

An examination of the data and the analytic results leads to several conclusions. The

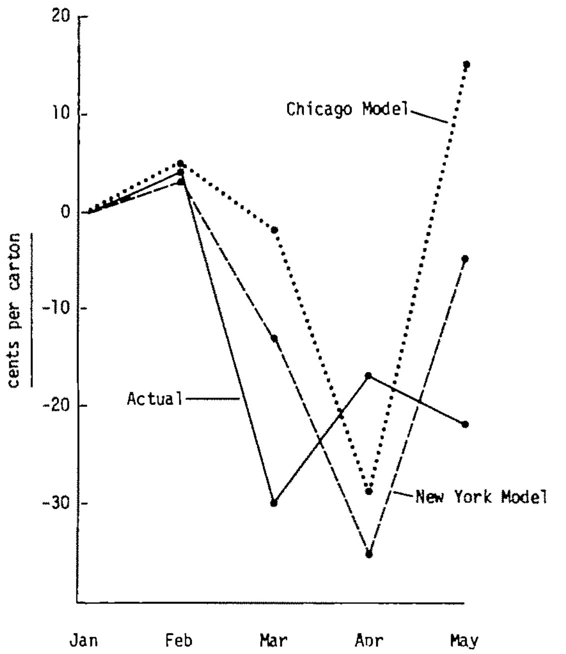

Figure 2. Actual and predicted wholesale price changes from a January base, January-May 1974 (based upon the restricted reduced form equations in table 1)

NOAC appears to have limited shipments with the results that (*a*) quantities available to consumers were lower, (*b*) retail prices were higher, and (*c*) grower and packer total receipts were lower. This third conclusion is surprising in view of whom NOAC represents, and we return to it at the end of this section.

Actual retail prices of navel oranges fell significantly as shipments increased in early 1975, contrary to NOAC assertions. New York retail prices, measured in current dollars, declined 63¢ per carton or 6.2% from January to April. Current dollar Chicago retail prices declined 48¢ per carton or 5.2% over this same period. While the fall in New York prices was less than predicted by the model, the analytic results in this paper support the CLC position that retail prices of fresh navels respond to shipments, i.e., the observed price decline was not a "fluke" but consistent with general behavioral patterns of consumers, retailers, and other middlemen. The estimated retail price flexibility consistent with the early 1974 context is −.4. Thus, consumers increased their total expenditures on fresh navels as shipments rose and prices declined.

The actual wholesale price (current dollars) fell 23¢ per carton or 6.2% from January to the March-April average. This decline was com-

parable in percentage terms to the drop in retail prices. The actual spread between wholesale and retail prices shrank over this period, which is consistent with the predictions of the models. There is no indication that "middlemen" were able to maintain retail prices at high levels while depressing shipping point prices as shipments rose. To the contrary, there is some evidence that wholesale-retail price spreads narrow at high levels of shipments.

Fresh navel shipments in February, March, and April were 54%, 55%, and 22% greater, respectively, than January shipments. The much smaller percentage decline in wholesale prices would seem to confirm the analytic results that NOAC was operating in the elastic portion of the demand curve. Comparing actual 1974 figures with actual 1973 figures, fresh navel shipments in February-April, 1974 were 130% greater than in February-April, 1973. Wholesale prices in March-May, 1974 were 15% below those of the same period in 1973. Even recalling that production of other fresh oranges declined from 1973 to 1974, the year-to-year comparison also is evidence of an elastic demand curve. Thus, there is little reason to believe the CLC action to increase shipments led to lower receipts for growers, as NOAC claimed, even if one were to account explicitly for packer charges. These results support the conclusion that total receipts to growers and packers increased.

We are puzzled by the actions of the NOAC with respect to its members' total receipts, assuming the analytic results are accepted. The following three hypotheses are suggested as a basis for further thought and analysis by others. First, restricting supply to the domestic fresh market was advantageous from an industry viewpoint because the demands faced in other outlets (primarily exports and processing) were even more elastic. Relative elasticities are the crucial factor in short-term marketing decisions. Second, restricting supply to the domestic fresh market was advantageous from an industry viewpoint of all producers of oranges. As noted earlier, the demand for all fresh oranges is less elastic than the demand for fresh navel oranges—and perhaps the former demand was inelastic. Third, the NOAC may simply have made a mistake, or borne a short-term economic cost, in the heat of an intense political battle. The objective of reducing the role of CLC in the food sector may have been so overriding that NOAC and USDA inadvertently or purposely ignored other objectives.

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Regional Economic Impacts of Policies To Control Erosion and Sedimentation in Illinois and Other Corn Belt States

Craig Osteen and Wesley D. Seitz

This analysis indicates that the adoption of different soil erosion control policies by different states in the Corn Belt will not result in significant shifts of production activities among the states. Some price impacts would occur but they would be felt throughout the region. More significant impacts may occur at the substate level. Farm operators on more erosive lands may be adversely affected. These results were generated using a general equilibrium linear programming model of crop production and markets in the Corn Belt.

Key words: Corn belt, crop production, economic analysis, erosion, linear programming, P.L. 92-500.

The Federal Water Pollution Control Act Amendments of 1972, P.L. 92-500, determined a nationwide goal of eliminating the discharge of pollutants into the nation's water by 1985. An interim water quality goal of "fishable, swimmable waters nationwide" by 1 July 1983, was also established. Under this law, each state was required to establish a "continuing planning process" for water quality management in order to achieve the stated goals. An important nonpoint pollution problem in Illinois and other Corn Belt states is erosion from agricultural lands and the associated sediment with its impacts on water quality.

The purpose of this paper is to present estimates of the spatial economic impacts of some alternative policies to control erosion and sedimentation. Individual states and areas within states are preparing separate plans under P.L. 92-500 so that there can be variations in degree of control of erosion and sedimentation between these states and areas. It is important to see what spatial economic impacts may occur if spatial variations in erosion controls exist. Policies investigated include restrictions on per acre soil loss which were applied: (*a*) only in Illinois, (*b*) uniformly in areas in the Corn Belt but outside of Illinois, and (*c*) uniformly in all Corn Belt states. The policies were aimed specifically at soil erosion control, because the relationships between erosion control policies and water quality have not been well defined at the current time.

Previous Research

The majority of work concerning the economic impact of soil erosion controls on a national or large subnational basis has taken place at the Center for Agricultural and Rural Development (CARD) at Iowa State University and the Department of Agricultural Economics at the University of Illinois.

A number of projects undertaken by CARD have considered the impacts of soil erosion controls. Wade and Heady attempted to link demand for agricultural commodities in the United States to sediment generated on cropland. A cost-minimizing linear programming model which accounted for spatial variation in commodity requirements, transportation costs, soil loss, and sediment delivery and transport was used. One of the model runs limited per acre soil losses on different land

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classes to soil loss tolerance levels. This restriction produced a large reduction, as compared to a benchmark run, in sediment load in the erosive areas of the southeastern and midwestern United States. Increased use of reduced tillage methods and terracing occurred. To reduce soil loss, costs were borne by producers.

Nagadevara, Heady, and Nicol used a similar model that did not account for sediment delivery and transport to examine the impact of applying soil loss restrictions in Iowa, while leaving the rest of the United States unregulated. The application of soil loss restrictions resulted in the removal of land in Iowa from crop production, less intensive production on more erosive soils, and increased soil erosion control practices. Soil loss in Iowa decreased while there was a greater increase in soil loss outside of Iowa. Farm income in Iowa decreased and production costs increased while land values and farm income increased outside Iowa.

Taylor and Frohberg (1977) used a linear programming model of the Corn Belt, with demand functions for corn and soybeans, to determine the economic impacts of erosion controls. The model accounted for variations in prices and production but did not account for transportation costs or sediment delivery or transport. They concluded that soil loss taxes were more effective in terms of social cost than terracing subsidies in reducing soil loss. With per acre restrictions, landowners gained while consumers lost; the opposite occurred with a soil loss tax. Detailed results are available in a forthcoming EPA report (Seitz et al.).

Method

A linear programming model of the Corn Belt economy was used to investigate the policies examined in the present study. The model used was a modification of the construct designed by Taylor to investigate policies to control nonpoint sources of pollution in the Corn Belt (Taylor and Frohberg). The model was applied to seventeen Land Resource Areas (LRAs) which produce approximately 70% of U.S. corn production and 60% of U.S. soybean production (Swanson and Taylor). The model was modified by separating the state of Illinois from other areas of the Corn Belt, incorporating a new method of including demand functions, and updating soil loss coefficients.

Part of this study parallels some of the work done by Nagadevara, Heady, and Nicol, by applying soil loss restrictions in some areas while leaving other areas unregulated. The model used in this study, however, was somewhat different since it accounted for variable prices and production. This feature helped reflect the impacts of policies on economic incentives which, in turn, may change prices. The impacts on producers and consumers could be more readily identified than with a cost-minimizing or constant price model.

Structure of the Model

The objective function in the model was producers' plus consumers' surpluses from the production of corn and soybeans minus the costs of production to meet requirements for wheat, oats, and hay. This function was maximized subject to the restrictions of the land base and environmental controls. The model was composed of two interdependent components which operated simultaneously: (*a*) a component that determines requirements for corn and soybeans, and (*b*) a component that minimizes the costs of producing corn, soybeans, wheat, oats, and hay to meet requirements on a fixed land base.

The component which determined requirements for corn and soybeans was defined by linear demand functions for corn and soybeans. These demand functions were specified by Taylor and Frohberg after review of a number of studies. The same demand functions were included in the model using a method described by Duloy and Norton. The method is conceptually equivalent but computationally more efficient than that used by Taylor and Frohberg.

Requirements for wheat, oats, and hay were determined outside of the model. (The additional costs of estimating demand functions for these crops and the additional computational costs in running the model were felt to be unjustified for this study.) Hay requirements were set for each LRA, while the requirements for wheat and oats were established for the Corn Belt. With the application of soil loss constraints, land was removed from production. It was assumed that land removed from row crop production due to the soil loss con-

straints would be allocated to hay production thus producing revenue for the landowner.

Each production activity in the cost-minimizing component was a crop rotation combined with a tillage practice and a conservation practice and was applied to a land capability unit (LCU) in a land resource area (LRA). Tillage practices included fall moldboard plowing, spring moldboard plowing, and chisel plowing. Conservation practices included straight-row plowing, contouring, and terracing. Terracing was limited to those LCUs on which it was an appropriate technique. Insect problems associated with conservation tillage, specifically the spread of cutworm were not accounted for. As a result, costs for conservation tillage may be understated. However, these costs were not considered to be a major obstacle to the use of conservation tillage (Moore).

The state of Illinois was defined by calculating the acreage of each LCU in an LRA within the state (Soil and Water Conservation Needs Committee of Illinois 1970). Each LRA was divided into areas inside and outside of Illinois. Because the Illinois portions of LRAs 95 and 105 were quite small, they were aggregated with LRA 108 in order to lower computation costs. Some of the relatively minor LRAs outside of Illinois were also aggregated to reduce computation costs. The total number of production regions was nineteen.

Soil loss coefficients used in this study were updated from those used in Taylor and Frohberg's study. The Soil Conservation Service has changed the inputs to the Universal Soil Loss Equation in recent years. Some of the assumptions concerning slope and slope length in LCUs and LRAs were changed in this study. Inputs for the Universal Soil Loss Equation were obtained from Lee and Kuder.

Results and Analysis

This section will discuss the estimates of impacts on soil loss and economic impacts on Illinois and Corn Belt farmers brought about by policies to control soil loss. The benchmark solution estimated what would occur under market conditions with no environmental control policies. Other runs of the model include: a soil loss restriction of 3 tons per acre per year (TAY) applied only in Illinois (policy I), a 3 TAY restriction applied in all Corn Belt states except Illinois (policy NI), and a 3 TAY restriction applied in the entire Corn Belt (policy CB).

Definition of Terms Used and Assumptions Required in Analysis

Economic terms discussed are now defined: social cost is $-1(\Delta PS + \Delta CS)$; ΔPS is change in producers' surplus relative to the benchmark:

$$\sum_{i=1}^{5}[(Q_{Ri} \times P_{Ri} - C_{Ri}) - (Q_{Bi} \times P_{Bi} - C_{Bi})]; \quad \text{and}$$

ΔCS is change in consumers' surplus relative to the benchmark:

$$\sum_{i=1}^{2}[(A_{Ri} - Q_{Ri} P_{Ri}) - (A_{Bi} - Q_{Ri} P_{Ri})] + \sum_{i=3}^{5}(Q_{Bi} P_{Bi} - Q_{Ri} P_{Ri}).$$

The following definitions relate to commodity i: A_{Bi} is area under demand curve for benchmark run; A_{Ri} is area under demand curve for soil loss restriction; P_{Bi}, price with benchmark run; P_{Ri}, price with soil loss restriction; Q_{Bi}, quantity produced with benchmark run; Q_{Ri}, quantity produced with soil loss restriction; and i, commodity; $i = 1$ for corn, $i = 2$ for soybeans, $i = 3$ for wheat, $i = 4$ for oats, and $i = 5$ for hay.

The prices of corn and soybeans were determined by the objective function. The prices of wheat, oats, and hay were imputed. In order to add producers' and consumers' surpluses and to make comparisons of social cost between runs, it was assumed that a dollar has the same value to all individuals. Social cost does not account for the environmental benefits and administrative costs brought about by a policy.

The Benchmark

Under the benchmark solution, producers' surplus was \$8.116 billion while consumers' surplus was \$11.001 billion. The correspondence between actual and benchmark crop acreages by LRA was similar in degree to the Taylor and Frohberg results; but there were some differences, and these differences partially explain the differences between their results and ours.

The model predicted that no land would be

terraced or contoured. These conservation practices increase the per acre cost of production without changing current yields. Future costs and benefits of conservation practices were not considered. Approximately 74% of the land in cultivation was under conservation tillage (chisel plowing). Reduced labor input lowered the per acre costs of production of conservation tillage relative to conventional tillage. The average soil loss on cropland planted in Illinois was estimated to be 2.97 tons per acre per year (TAY).

Other estimates of the current condition of land use and soil loss are somewhat different. It has been estimated that the average soil loss on Illinois cropland under current conditions is 5.1 TAY (Kuder). It also has been estimated that there are less than 250,000 acres of terraced land in Illinois while there are approximately 1.3 million acres of contoured land in Illinois (Ives). Approximately 28% of Illinois cropland was chisel plowed in 1976 (Lessitor). The large acreage in conservation tillage in the benchmark as compared to the current situation accounts for low estimate of soil loss. The model implies that there may be a substantial increase in conservation tillage in Illinois and throughout the Corn Belt due to lower labor costs. This increase in conservation tillage may bring about a large decrease in soil loss from the current condition without soil erosion control by government.

Soil Erosion Policies

Economic impacts in the Corn Belt. The results of applying soil loss restrictions to the model show that society will bear a cost to control soil erosion with all policies. Producers and consumers do not share the cost equally and the incidence of the cost changes with the area of application of the soil loss restriction. With policy I, producers' surplus increased and consumers' surplus decreased, while the opposite occurred with policy NI and CB. These results are shown in table 1.

Social cost increased as the area of application increased from Illinois to areas outside Illinois to the entire Corn Belt. Social cost increased from $15 million for policy I to $48 million with Policy NI to $64 million with policy CB.

Producers' surplus increased by $36.4 million with policy I, decreased by $339 million with policy NI and by $322 million with policy CB as compared to the benchmark. Consumers' surplus decreased by $49.6 million with policy I, increased by $29.1 million with policy NI, and by $258 million with policy CB.

With policies NI and CB, consumers' surplus increased while producers' surplus decreased. These results conflict with Taylor and Frohberg's findings that producers' surplus increased while consumers' surplus decreased when a soil loss restriction was

Table 1. Changes in Economic Variables Due to Soil Erosion Policies

		Changes from Benchmark Due to 3 TAY Soil Loss Restriction		
Item	Benchmark	Policy I	Policy NI	Policy CB
Social cost (million $)	0	15.0	48.0	64.0
Consumers' surplus (million $)	0	−49.6	291.0	258.0
Producers' surplus (million $)	0	36.4	−339.0	−322.0
Production cost (million $)	0	6.0	2.0	26.5
Gross revenue (million $)	0	36.3	−337.0	−295.0
Commodity prices				
Corn	2.57	2.58	2.52	2.48
Soybeans	5.45	5.45	5.76	5.87
Wheat	4.84	4.84	4.21	4.46
Oats	2.38	2.38	2.04	2.07
Hay	56.17	56.31	53.64	54.18
Commodity production (in billion bu.)				
Corn	3.662	3.653	3.700	3.754
Soybeans	0.760	0.759	0.719	0.705
Wheat	0.227	0.227	0.227	0.227
Oats	0.372	0.372	0.372	0.372
Hay (million tons)	25.937	26.132	27.269	27.464

applied in the Corn Belt. The reason for these differences will be discussed in the section on prices and production.

Prices and production. Soil loss restrictions required that erosion control practices be used with some crop rotations on some LCUs. These erosion controls increased the costs of producing crops. These cost changes had impacts on crop prices, production, and acreages. Since crops had varying erosion rates, soil loss restrictions had different impacts on the prices of each crop. Thus the relative returns of crops changed and farmers changed their production mixes in such a way as to maximize income under the constraint.

Table 1 illustrates commodity prices and commodity production for each policy. Soybean production decreased and price increased as the area of the restriction increased from policy I to policy NI to policy CB. Corn price decreased and production increased. The prices of wheat, oats, and hay generally decreased when soil loss restrictions were applied but a pattern of price changes was not readily apparent.

Since soybean production generates higher soil erosion rates than other crops, the cost of meeting the restriction was higher with soybean production than for other crops, thus soybean production decreased. Decreasing soybean production opens land for the production of the other crops. Prices of wheat, oats, and hay decreased due to shifts to more fertile land. Corn also was allocated to this land in policies NI and CB when corn production increases.

The changes in prices and production impact producers' and consumers' surpluses. The decrease in consumers' surplus with policy I was the result of the small increases of corn and hay prices while other prices remained constant. The increase of corn and hay prices in the price-inelastic portions of demand curves increased producers' surplus.

The decrease in all prices except soybeans relative to the benchmark in policies NI and CB resulted in an increase in consumers' surplus. Soybean price increased in the price-elastic portion of its demand curve while the prices of other crops decreased in price-inelastic areas causing gross revenue to decrease. The decrease in revenue and the increase in erosion control costs caused producers' surplus to decrease in policies NI and CB.

The changes in producers' and consumers' surpluses resulting from a 3 TAY soil loss restriction throughout the Corn Belt differ in this model and Taylor and Frohberg's. This occurs because soybean price increases and corn price decreases relative to the benchmark in this work while both increase in Taylor and Frohberg's work. The different method of including demand curves in this model may have had some impact. The two methods might not be exactly equivalent computationally. Also, in converting to the new method, some economic incentives may have been changed through computations made in the process. In this model also, more soybeans and less corn were allocated to erodable areas in the benchmark solution. As a result, more soybeans were removed from production, while corn production increased. Aggregation of LRAs that generated slightly different costs and yields appears to have caused the difference in crop allocations.

Regional economic impacts. The results show that there will be very little impact on Illinois' comparative economic advantage in crop production if Illinois is the only state to restrict soil loss, if it is the only state not to restrict soil loss, or if it cooperates with all other states in restricting soil loss.

The impact of the policies on Illinois' share of producers' surplus includes the impacts of price changes, erosion control costs, and shifts of production between regions. Price changes which were brought about by soil loss restrictions had the same impact on per acre returns for a crop in unrestricted areas as in restricted areas causing producers' surplus to change in the same direction in both areas. Erosion control costs, however, tended to cause producers' surplus in restricted and unrestricted areas to change in opposite directions due to erosion control costs and production changes required in restricted areas only. Erosion control costs changed economic incentives for crops in different regions causing production shifts. Production shifts tended to moderate decreases in producers' surplus in Illinois.

The small impact on Illinois' comparative advantage is demonstrated by the small change in Illinois' share of producers' surplus for all policies as compared to the benchmark. Illinois had a producers' surplus of $1.996 billion, which is 24.6% of producers' surplus for the Corn Belt. Producers' surplus in Illinois decreased by $47 (to 23.9%) million with pol-

icy I, by $113 (to 24.2%) million with policy NI, and by $133 (to 24%) million with policy CB. The maximum decrease in Illinois' share of producers' surplus is 0.7%.

The results of policy I are consistent with the findings of Nagadevara, Heady, and Nicol; that is, income in the unregulated area increased while it decreased in the regulated area. With policy NI, however, income decreased in both the regulated and unregulated areas. This result occurred because price and production changes were brought about by application of the soil loss restriction. Total corn production and Illinois' share of corn production decreased slightly relative to the benchmark from policy I to policy NI to policy CB. Illinois' share of soybean production increased from approximately 15% for the benchmark and policy I to 16% for policies NI and CB. This shift from corn to soybeans in Illinois under policies NI and CB, while the opposite occurs outside, generated the slight income shifts.

Producers' surplus decreased only slightly in Illinois with policy I because the prices of corn and hay increased while Illinois maintained a high share of corn production. These price increases tended to offset decreases in revenue caused by decreasing production of corn, soybeans, wheat, and oats. The primary reason for the larger decrease in producers' surplus in Illinois with policies NI and CB than with policy I was the decrease in the prices of corn, wheat, oats, and hay.

The shift of soybeans into and corn out of Illinois under policies NI and CB was the result of farmers outside of Illinois substituting corn for soybeans to reduce erosion control costs. As a result, corn price decreased and soybean price increased. These price changes encouraged Illinois farmers to substitute soybeans for corn. Under policy NI, there was no soil loss restriction in Illinois to limit the planting of soybeans. There was a restriction under policy CB which resulted in less Illinois soybean production than under policy NI. However, the flat land of Illinois has lower erosion rates than some other areas of the Corn Belt resulting in lower erosion control costs in Illinois. These lower costs encouraged the crop shift. It appears that these crop shifts, though small, moderated the decrease of producers' surplus under policies NI and CB.

Economic impacts within Illinois. The economic impacts on Illinois of these three policies were not evenly distributed within the state. The most severe income reductions occurred on lands with high slopes and more erodable soils, more prevalent in southern Illinois, in general, than other areas of the state. These areas required more expensive erosion control practices and changes in crop rotations to meet the soil loss restriction than flatter land and less erodable soil. These changes had impacts on prices which, in turn, affect returns per acre on land not needing erosion control practices.

Under policy I, average change in returns per acre varied from a gain of $0.47 per acre in LRA 110 to a reduction of $2.36 in LRA 113. The small gains were the result of small increases in the prices of corn and soybeans. With policy NI, average per acre change in returns varies from a reduction of $3.71 per acre in LRA 115 to a loss of $6.02 in LRA 113. With policy CB, average per acre change varies from a loss of $4.30 in LRA 114 to a loss of $10.71 in LRA 113. With policies NI and CB, the prices of all commodities except soybeans decreased. These price decreases resulted in losses to all land in Illinois.

Income gains and reductions were not evenly distributed among land classes. The largest reduction in returns per acre occurred on LCUs 2E, 3E, and 4E, that is land with an erosion problem and relatively high slope, under policies I and CB, but not under policy NI. Under policies I and CB, changes in crop rotations and applications of erosion controls were needed to meet the soil loss restriction.

The greatest changes in land management and the largest reductions in returns per acre occurred on LCUs 3E, 4E, and 58, which aggregated SCS soil classes 5 through 8, in LRA 113 in southern Illinois. Soils in LRA 113 are more erodable than soils in other areas of Illinois. As a result, economic impacts were greater in LRA 113 than in other LRAs.

The importance of price impacts on per acre returns can be appreciated by comparing the policies. Per acre losses in policies NI and CB were, in general, considerably larger than in policy I. The differences in per acre losses between policies NI and I on W subclass soils in particular showed that price impacts alone can cause very large changes in per acre returns. Soil erosion control practices were not applied to these soils due to extremely low soil losses. With policy I, all W subclass soils showed increases in per acre returns due to

increases in the price of corn but with policies NI and CB, the per acre returns on these soils decreased due to decreases in all crop prices except soybean price.

Soil loss and conservation practices. Soil loss restrictions have impacts on land management practices and soil loss from land. Soil loss decreased in the restricted area and increased in the unrestricted area, however, the decrease in soil loss in the restricted area was greater than the increase in the unrestricted area. These results are different than those reported by Nagadevara, Heady, and Nicol, which showed that soil loss increased more outside Iowa than it decreased in Iowa.

Soil loss in Illinois decreased by approximately 33 million tons relative to the benchmark with policies I and CB. Soil loss outside Illinois increased by 66,000 tons relative to the benchmark with policy I, decreased by 359 million tons with policy NI, and by 352 million tons with policy CB. Soil loss outside Illinois was 7.4 million tons greater with policy CB than with policy NI. Total soil loss in the Corn Belt decreased by 32.7 million tons with policy I, by 348.6 million tons with policy NI, and by 384.5 million tons with policy CB.

Applying soil loss restrictions has a very large impact on conservation practices. Over 30% of Illinois' area and over 45% of the area outside of Illinois is shifted into conservation practices (terraces and contouring) when a 3 TAY restriction is applied. Approximately 1.1 million acres of land in Illinois were allocated to terracing and 6 million acres to contouring under policies I and CB.

The impact of soil loss restrictions on tillage practices relative to the benchmark is less dramatic. This is due primarily to the high percentage of conservation tillage in all runs including the benchmark, which produces less soil loss than fall and spring plowing.

Policy Implications

There is variation in the economic consequences of applying soil loss restrictions on areas of varying sizes as might occur under P.L. 92-500.

Soil loss restrictions caused relatively small social costs ranging from $15 million for policy I to $64 million for policy CB. The price effects and costs of soil erosion controls brought about relatively large decreases in returns to landowners and decreases in expenditures to consumers with policies NI and CB. These results disagree with those of Taylor and Frohberg, where producers' surplus increased and consumers' surplus decreased. The distribution of crops on erodable soil before a restriction is applied appears to be important in determining price impacts. Under policy I, there were relatively small increases in returns to landowners and consumer expenditures. Taken together, these results and Taylor and Frohberg's results may imply that the economic impacts on producers may be quite small.

The impact of the three policies on Illinois' comparative advantage in agricultural production, that is, Illinois' share of producers' surplus, was insignificant. This occurred because the impacts of the policies on prices affected both regulated and unregulated areas. Shifts of production between regions seemed to have much less impact on producers' surplus in a region than changes in crop prices.

The economic impacts of these policies were unevenly distributed in Illinois. Under policies NI and CB, there is a large burden on a relatively small group in Illinois, the owners of erodable land.

The model predicts that there will be a decrease in both corn and soybean production when a soil loss restriction is applied only in Illinois. When a soil loss restriction is applied outside Illinois or in the entire Corn Belt, the model predicts that soybean production will decrease and corn production increase in the Corn Belt, while soybeans shift to Illinois.

Soil loss was reduced by changing crop patterns, tillage practices, and conservation practices with all three policies. With policies I and NI, soil loss decreased in regulated areas but increased, to a lesser degree, in unregulated areas. Coordination of the policies of the different states would minimize these transfers of soil loss between states. However, total soil loss would still decrease if one state enacted a soil erosion control policy while others did not, and the income impacts on agriculture in that state would not be large.

The model predicts that economic incentives will encourage farmers to adopt conservation tillage methods and reduce soil loss. Government action through financial assistance or soil loss restrictions would not be needed to bring about the decrease in soil loss associated with the adoption of conservation tillage. Education programs emphasizing the

financial advantages of conservation tillage, as well as the soil conservation aspects, could be instituted and continued to encourage the adoption of conservation tillage. Conservation tillage, however, may not always meet SCS soil loss goals.

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Notes

On the Statistical Estimation of Isoquants And Their Role in Livestock Production Decisions

Oscar R. Burt

Animal production experiments permit limited control of experimental factors because the animals themselves partially determine total feed consumption per unit of time. Within practical limits, the variables that economists would like to have as controlled factors in the experiment are not subject to direct control, but instead, are controlled indirectly by other closely related variables.

The problems involved are illustrated by a recent article of Sonka, Heady, and Dahm. In a swine-feeding experiment, percentage of protein in the ration was the only design variable, but economists would have liked to see corn and protein supplement as the controlled factors since they are the direct inputs for which there exist price quotations. Of course, other variables besides percentage of protein can be thought of as the single controlled factor; either percentage of the ration by weight which is corn or a standardized protein supplement would serve equally well. The important point to be recognized is that the controlled factors are different than the direct feed inputs and one less in number because the animals themselves control total feed consumption per unit time. In the swine-feeding experiment analyzed in Sonka, Heady, and Dahm, percentage of protein is the single factor instead of the pair of variables, corn and protein supplement consumption.

Data from the swine-feeding experiment can be analyzed in two basic ways: (*a*) weight gain, corn consumption, and protein supplement consumption per unit of time are treated as multivariate responses to the single controlled factor, namely, percentage of protein in the ration; and (*b*) weight gain is divided into discrete intervals, and for each of these intervals, corn consumption, protein supplement consumption, and time required to achieve a specific gain are treated as multivariate responses to the single experimental factor. Following (Sonka, Heady, Dahm), we consider only the latter type of analysis which simplifies statistical estimation problems.

Adopting most of the notation in Sonka, Heady, and Dahm, there are three equations of possible economic interest to be estimated from the experimental data:

(1) $$C_i = f_i(R_i),$$

(2) $$S_i = g_i(R_i), \text{ and}$$

(3) $$D_i = k_i(R_i),\ i = 1, 2, 3.$$

The variables C_i, S_i, D_i, and R_i are corn consumption, protein supplement consumption, days required to attain the ith level of gain, and percentage of protein in the ration, respectively. The three intervals, $i = 1, 2, 3$, are associated with gains of 60 to 100, 100 to 150, and 150 to 215 pounds, respectively.

Economic Analysis and Isoquants

Statistical estimation of (1) through (3) is discussed later, letting us concentrate on the economic analysis now. The approach taken in Sonka, Heady, and Dahm largely follows that of classical production economics with considerable emphasis on empirical estimation of isoquants. Let us suppose that statistical estimates of (1) and (2) are available; therefore, C_i and S_i are the mathematical expectations of the dependent variables in the statistical equations, as are the right hand side functions of R_i. We drop the subscript i for the separate gain levels in order to simplify the notation in the following discussion.

Since a specific protein percentage R implies mean consumption levels for each corn and protein supplement as given by (1) and (2), we have an implicit equation between C and S, i.e., an isoquant for mean levels of corn and protein supplement consumption. The parametric representation of an isoquant by (1) and (2) is clarified by thinking of plotting the pairs of points (C,S) associated with various values of R; the locus of these points is the isoquant (see Sherwood and Taylor, p. 171, on parametric representation of functions).

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However, another way to look at the isoquant is to think of it as a change of variable for the economically relevant functions associated with the experiment. If we treat the average quantity of protein supplement consumed as the independent variable in the algebraic expression of the isoquant, then percentage of protein in the ration has been removed as the key variable and replaced by pounds of protein supplement. If (3) is needed in the economic analysis, R can be replaced by S by using (2) and (3) as a parametric representation of a functional relationship between D and S.

These ideas are clarified by going through the economic analysis under simplifying assumptions. Let us consider the case where costs and gross returns are not dependent on length of time required to reach an a priori specified market weight for the hogs. This problem reduces to minimizing feed costs per head to achieve each of the three gain levels (see Sonka, Heady, Dahm). Remember that the subscript i has been dropped in the notation and we are looking at a particular gain level.

Let corn and protein supplement prices be denoted by P_c and P_s, respectively. Then total feed costs for a particular gain level are $FC = P_cC + P_sS$, which reduces to

$$FC = P_cf(R) + P_sg(R), \tag{4}$$

when C and S are replaced by the right hand sides of (1) and (2), respectively. Note that the economic problem is simply the minimization of a cost function in one variable, percentage of protein in the ration.

Differentiation of (4) with respect to R and setting the result equal to zero gives the necessary conditions for an interior solution to minimum cost:

$$P_cf'(R) + P_sg'(R) = 0, \tag{5}$$

or assuming $g'(R) \neq 0$,

$$P_s/P_c = -f'(R)/g'(R). \tag{6}$$

Since $dC = f'(R)dR$ and $dS = g'(R)dR$, we can interpret the right hand side of (6) as $-dC/dS$, i.e., the marginal rate of substitution of C for S, or the negative of the slope of the isoquant.

If we were to derive the isoquant from its parametric representation given by (1) and (2), the result would be a unique function for a particular orientation of the axes. The algebraic form might be very impractical to derive, but we could always plot points and get a graphic approximation with arbitrary accuracy. When S is taken as the abscissa, let the iosquant be denoted as $\phi(S)$, i.e., $C = \phi(S)$. Then, if we use $\phi(S)$ in the feed cost equation, (4) is replaced by

$$FC = P_c\phi(S) + P_sS, \tag{4$'$}$$

which now has protein supplement consumption as a variable instead of percentage of protein in the ration. Necessary conditions for a minimum are

$$P_s/P_c = -\phi'(S) = -dC/dS, \tag{6$'$}$$

but, as shown before, $\phi'(S) = f'(R)/g'(R)$.

The purpose of these simple derivations was to show that isoquants are in some respect redundant, and merely make a change of variable in the criterion function for the economic analysis. The most important consideration is whether percentage of protein in the ration or mean consumption of protein supplement to achieve a given level of gain is a more practical variable for economic decisions. The author would choose percentage of protein in the ration and thus avoid the derivation of isoquants.

On the basis of textbook theory, (6)′ has a certain appeal, but we should keep in mind that livestock producers face the same problems of feed consumption control as technicians conducting experiment station research. It would appear that the economic analysis would best be reported in the same variables as the controlled factors of the experiment. This would appear to be the opinion of Sonka, Heady, and Dahm, too, since their main empirical results are reported with percentages of protein in the ration (see tables 2 and 3, Sonka, Heady, Dahm). However, these authors did their economic analysis within an isoquant framework which is a rather roundabout way to get the results. The advantages of a direct approach, using (1) and (2), are more pronounced when the statistical estimation problems are also considered.

If time per se enters into the economic analysis, i.e., the problem is dynamic instead of static, then the criterion function is more complicated. The same general ideas developed above for the static case still apply with respect to choosing the form of the decision variables.

Statistical Estimation

The economic analysis above has treated the equations (1) through (3) as nonstochastic. Let us now think of statistical error terms having been added to the right hand sides so that the dependent variables are random, and we are faced with statistical estimation of the systematic parts represented as functions of R_i. In the economic analysis, the dependent variables were taken as mean values of the experimental response variables.

In regard to statistical estimation of the nine equations involved in (1) through (3), the most efficient method is to treat them as a system and exploit the obvious tendency of residuals on the same experimental unit to be correlated among the equations. The simplest methodology is that of "seemingly unrelated regressions" (Theil, chap. 7), but maximum likelihood estimates under the assumption of normality are obtained by repeated iterations on the covariance matrix (Malinvaud, chap. 9). However, the experimental data for the system of equations will have a singular covariance matrix for the disturbances which requires some special consideration.

Let the statistical equations for (1) and (2) for a particular weight gain interval and experimental observation be

$$(7) \qquad C = f(R) + u, \text{ and}$$

$$(8) \qquad S = g(R) + v.$$

For a given percentage of protein in the ration, R, and a given consumption level of protein supplement, S, the consumption level of corn is determined exactly. Consequently, the disturbances u and v have correlation equal to one, and a mathematical constraint exists on the functional forms of $f(R)$ and $g(R)$.

Let π_c and π_s be the percentage of protein in corn and the protein supplement, respectively. Then, by definition,

$$R = (\pi_c C + \pi_s S)/(C + S),$$

which can be manipulated to give

$$(9) \qquad C = [(\pi_s - R)/(R - \pi_c)]S.$$

Substitution of (7) and (8) into (9) and taking expectations on the random variables u and v gives

$$(10) \qquad f(R) = [(\pi_s - R)/(R - \pi_c)]g(R).$$

Since (10) must hold for the systematic parts of (7) and (8), we have a fixed relationship between the disturbances

$$(11) \qquad u = [(\pi_s - R)/(R - \pi_c)]v,$$

for each experimental observation.

When $f(R)$ and $g(R)$ are linear in parameters, it can be shown that the generalized least-squares estimation of (7) and (8), using the generalized inverse of a matrix to deal with the singular disturbance covariance matrix, reduces simply to deleting one or the other of the equations and estimating the other alone. The second equation is estimated by (10). The proof is rather apparent from problem 7.3 in Theil (p. 281). In regard to statistical estimation of the systems of nine equations in (1) through (3), three of the equations are deleted from the system, say (1) for $i = 1, 2, 3$, and only the remaining six equations are estimated simultaneously. If all the equations to be estimated as a system are of the same functional form, linear in the parameters, and the data points on the independent variables are identical across equations, the simultaneous estimates of the parameters are the same as single equation estimates (Theil, p. 311).

If the isoquants are of interest, for whatever reason, least squares estimation of (8) alone, without the benefit of simultaneous estimation of the system of equations, then derivation of $\hat{f}(R)$ using (10), and derivation of the isoquants by means of the parametric representation implied by $\hat{f}(R)$ and $\hat{g}(R)$ is more efficient statistically than using the instrumental variable approach of Sonka, Heady, and Dahm. Under the assumption of normality for the statistical error terms and maximum likelihood estimates of $f(R)$ and $g(R)$, the implicit estimates of the isoquants are also maximum likelihood through the invariance property of maximum likelihood estimators (Goldberger, p. 131).

What Sonka, Heady, and Dahm used and called an instrumental variables method of estimation for the isoquants is more specifically a two-stage least squares method for the following model:

$$(12) \qquad \ln(C) = \alpha + \beta \ln(S) + e_1, \text{ and}$$

$$(13) \qquad \ln(S) = Q(R) + e_2,$$

where C and S are assumed jointly dependent and R exogenous, e_1 and e_2 are random errors, and $Q(R)$ is a quadratic function in R.

The model of (12) and (13) in conjunction with two-stage least squares estimation provides an estimation procedure which is quite intuitive since $\ln(C)$ is regressed on least squares predicted values of $\ln(S)$ which were estimated from (13). One aspect that is a little troublesome logically is the obvious symmetry between the variables C and S; a model where these two variables were interchanged in (12) and (13) would be equally plausible, but would give different results for the isoquant.

A more fundamental objection to the two-stage least squares estimation procedure emanates from the identity that exists between C and S, given by (9). The isoquant is already implied by estimation of (13) in the first stage, and the second-stage least squares fit can be nothing more than fitting a particular algebraic function to that isoquant, the algebraic form of which already was determined in the choice for the first stage, namely, the specification in (13). The problem is illustrated below with the results presented by Sonka, Heady, and Dahm.

Let us use the second weight-gain interval of the swine-feeding experiment as an example. Sonka, Heady, and Dahm estimated the following equation for protein supplement consumption in relation to percentage of protein in the ration:

$$(14) \qquad \hat{g}(R) = \exp(-3.483 + .7962R - .0225R^2).$$

The protein supplement used for this gain interval was 41% protein, and we assume 8.5% protein for corn. The estimate of corn consumption in relation to R follows from (10), giving

$$(15) \qquad \hat{f}(R) = (41 - R)\hat{g}(R)/(R - 8.5),$$

where $\hat{g}(R)$ is as given in (14).

Substitution of specific values of R into (14) and (15) and plotting the coordinates for the expectation of S and C as given by (14) and (15), respectively, lets us graph the isoquant. Application of this procedure gave the "derived" isoquant in figure 1, where the "fitted" isoquant obtained by Sonka, Heady, and Dahm is also graphed for comparison. Note the inflection point in the derived isoquant at about 22 pounds of protein supplement, which corresponds to 13.2% protein in the ration. The fitted isoquant, using a double-log model, is seen to be a fair approximation to the derived isoquant as far as

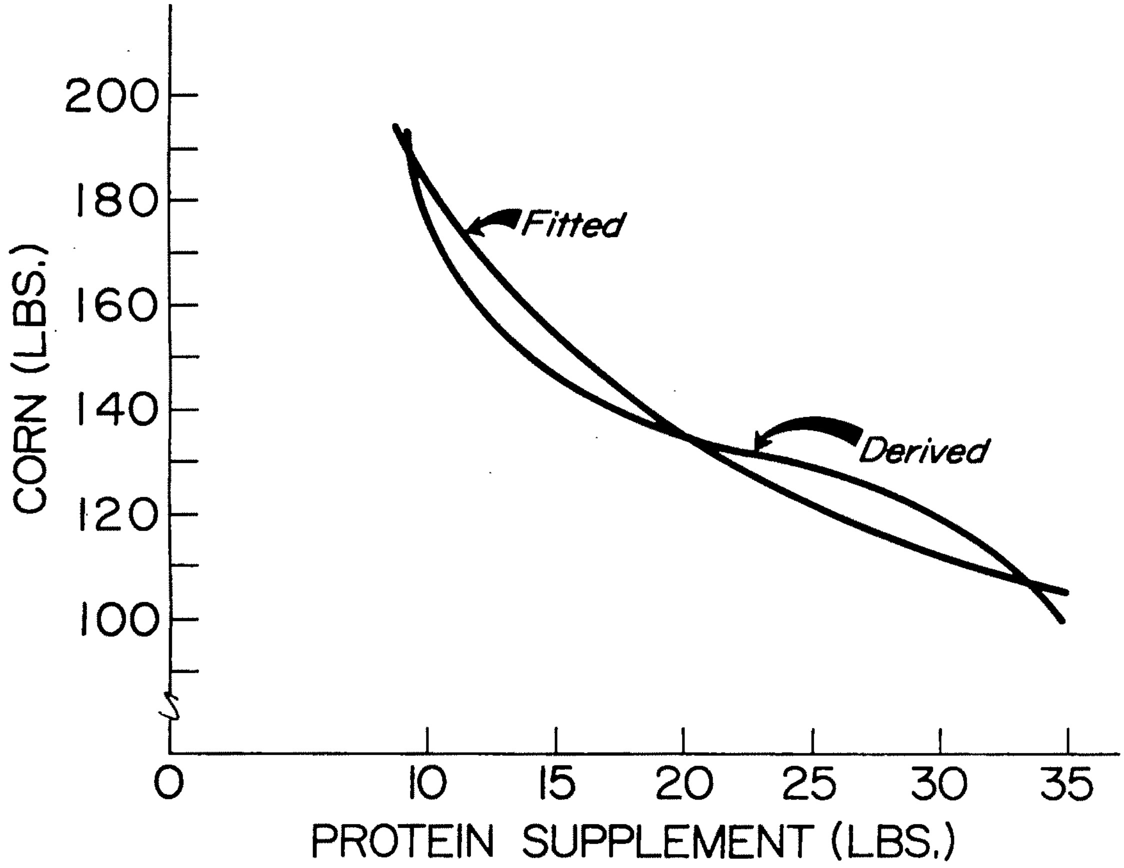

Figure 1. Contrast of isoquants for weight gain interval II

the level of corn consumption is concerned, but its shape and, consequently, the marginal rates of substitution are much different.

The inflection point in the derived isoquant could stem from the algebraic form specified by (14), and this certainly warrants investigation. Marginal rates of substitution were calculated for the other two gain intervals, and in each case, the rates increased at upper levels of protein in the ration. In each of the three gain intervals, the inflection point of the isoquant corresponded closely to the mean level of percentage of protein in the ration for the experiment. This tendency for symmetry with respect to the convex and concave segments of the isoquants suggests that the functional form used by Sonka, Heady, and Dahm for $g(R)$ forces an inflection point on the isoquants.

Of course, a convex function can always be fitted to the nonconvex isoquant implied by the choice of $g(R)$, much as did the procedure used by Sonka, Heady, and Dahm, but we would expect greater statistical efficiency by choosing the form of $g(R)$ such that the empirical isoquant directly implied is convex without a second fitting to achieve convexity. In view of Brokken's recent work on isoquants for cattle feeding where he builds a strong case for isoquants not being convex, we should be cautious in using "a priori knowledge."

We would be interested in the statistical precision of the estimation of (7) and (8), but under the assumptions which imply feed cost minimization as the economic criterion, the key functional relationship is the marginal rate of substitution,

$$\eta(R) = f'(R)/g'(R), \tag{16}$$

as can be seen from (6). Let us suppose that $\hat{g}(R)$ has been estimated and $\hat{f}(R)$ is estimated by (10); then

$$\hat{\eta}(R) = \frac{\pi_s - R}{R - \pi_c} - \frac{\pi_s - \pi_c}{(R - \pi_c)^2} \cdot \frac{\hat{g}(R)}{\hat{g}'(R)}. \tag{17}$$

A standard error for $\hat{\eta}(R)$ in (17) could be approximated by routine methods which use a linear approximation to a nonlinear function of random variables to derive an estimate of the variance of the function (Theil, p. 374). Note that the only stochastic part of (17) is the ratio $\hat{g}(R)/\hat{g}'(R)$.

A point estimate of the economically optimal percentage of protein in the ration for given prices of corn and supplement would be obtained by solving

$$\hat{\eta}(R) = P_s/P_c, \tag{18}$$

in the variable R. In the range of the experimental data where $\hat{\eta}(R)$ is decreasing, i.e., the economically relevant range of (18), an inverse function for $\hat{\eta}(R)$ exists conceptually such that

$$R = \hat{\eta}^{-1}(P_s/P_c). \tag{19}$$

In principal, a standard error could be approximated for the inverse function $\hat{\eta}^{-1}(\cdot)$, which could be used to get an approximate confidence interval for the economically optimal level of R for any given price ratio, P_s/P_c.

Since (19) and the standard error for $\hat{\eta}^{-1}(\cdot)$ would usually be a problem to derive, a graphical approach to the confidence interval might be more practical. This approach would use (18) and a standard error for $\hat{\eta}(R)$ to derive confidence bands for $\eta(R)$ under a normality assumption for $\hat{\eta}(R)$. Such confidence bands are illustrated in figure 2. These confidence bands can be used to obtain a confidence interval for the economically optimal level of R, which is denoted by R^*, for a specified price ratio P_s/P_c. The method is illustrated in figure 2. Intersection of the price ratio line with the lower band at A and the upper band at B determines the confidence interval.

$$P_r(R_L \leq R^* \leq R_U) = \gamma, \tag{20}$$

where γ is the probability of the vertical interval between the bands covering the function $\eta(R)$.

If the statistical precision on $\hat{\eta}(R)$ is too low relative to γ, one or the other of the intersection points, A or B, may not exist and only a one-sided confidence interval is possible for γ at that level or greater. One compromise would be to decrease γ until both intersection points A and B exist for the price level of interest. The kinds of problems encountered in "reverse regression" confidence intervals (Graybill) do not occur here because both R and P_s/P_c are nonstochastic.

After getting the confidence interval in (20), the range of error in the minimum cost criterion can be subjectively evaluated by substituting the limits R_L and R_U into the cost function for comparison with cost calculated from the point estimate implied by (18).

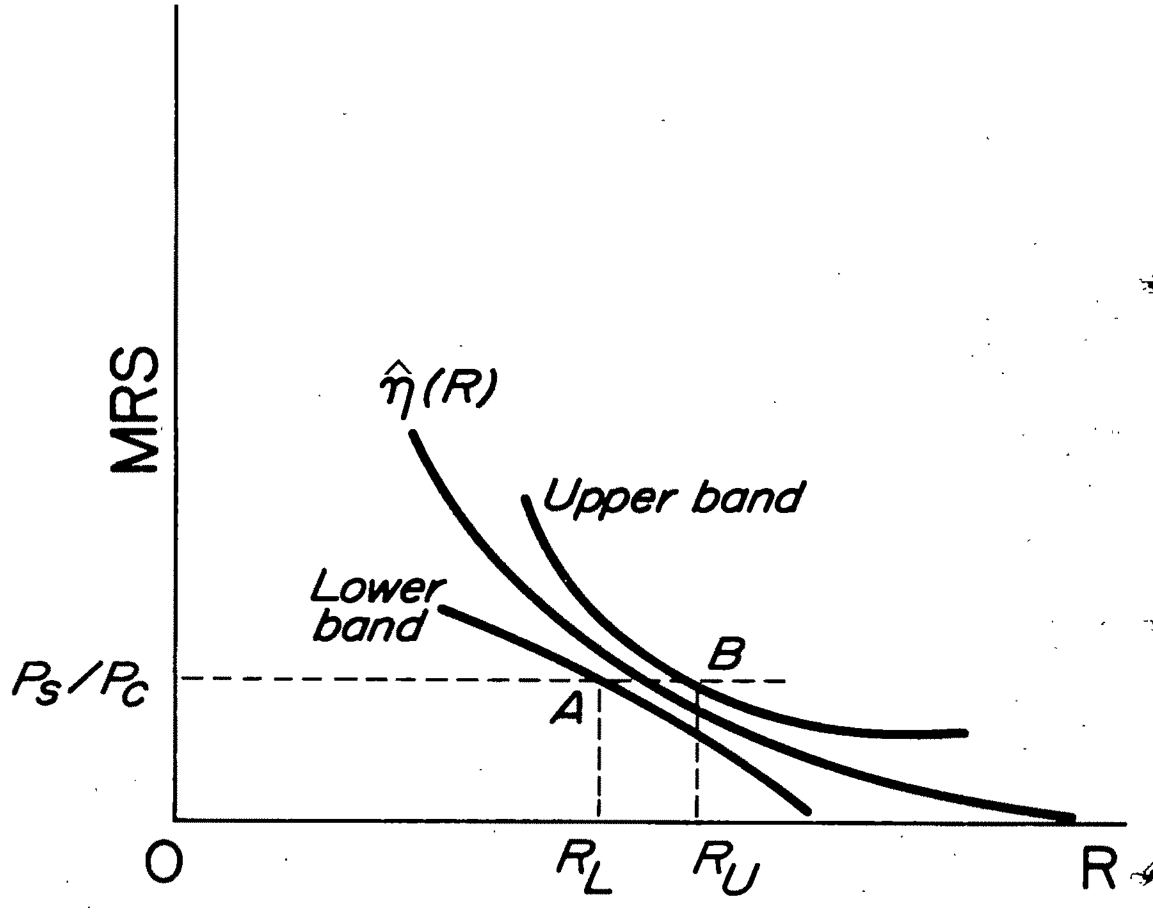

Figure 2. Confidence interval for optimal protein percentage in the ration

variance reduction is directly dependent upon the degree of multicollinearity, ρ, while the bias is independent of ρ. In the present case the use of the average root criterion would lead to the deletion of one component irrespective of potential variance reduction. Instead the characteristic root spectrum should be investigated through the spectral decomposition of the OLS estimator covariance matrix. Since $\mathrm{tr}\ \sigma^2(X'X)^{-1} = \mathrm{tr}\ \sigma^2 A\Lambda^{-1}A' = \sigma^2 \sum_{i=1}^{K} (1/\lambda_i)$, the percentage of variance reduction from deleting components associated with the smallest $(K - r)$ characteristic roots is

$$\left\{\mathrm{tr}\left(\sum_{i=r+1}^{K} \frac{1}{\lambda_i} a_i a'_i\right) \Big/ \sum_{i=1}^{K} (1/\lambda_i)\right\} \times 100.$$

Any rule involving inspection of characteristic roots should be based upon the gain available in each specific problem; though, of course, potential losses cannot be determined from the spectrum.

Tests of PC Restrictions

Of course if the PC restrictions are invalid ($A'_2\beta \neq \mathbf{0}$) then $\hat{\beta}^*$ is biased and inconsistent. However, it is possible that these restrictions may yield a MSE gain. The question is not a matter of the PC restrictions being exactly "true" or "false," but whether or not they add information which, though not included in the original maintained hypothesis, is approximately correct. A sufficient condition for this situation to arise is when the principal components, z_i, are interpretable (say as an index of some sort) and it is felt that some are not important in the sense of having a causal effect on the dependent variable. In such a case, the Toro-Vizcarrondo-Wallace test offers a valid framework for evaluating the potential MSE gain derivable from using the new principal components specification.

On the other hand, the absence of interpretable principal components puts an investigator in a precarious position with respect to MSE tests. As Toro-Vizcarrondo and Wallace have noted (p. 569), MSE tests should not be used in a mechanical way. Mechanical application of such tests leads to the possibility of accepting spurious restrictions, and hence, implied small sample gains could be illusory.

The futility of imposing sample specific restrictions in the absence of interpretable components (knowledge of δ_i) becomes obvious in view of some basic results which have recently been derived in the preliminary test literature (Bock, Yancey, Judge; Judge, Bock, Yancey; and Wallace and Ashar). Suppose, for example, that an investigator proposes to choose between the OLS estimator, $\hat{\beta}$, and the PC estimator, $\hat{\beta}^*$, with restrictions $A'\beta = \mathbf{0}$ based upon the outcome of a test of the hypothesis $H_0: A'_2\beta = \mathbf{0}$, versus $H_1: A'_2\beta \neq \mathbf{0}$. This selection leads to a preliminary test principal components (PTPC) estimator which can be defined as:

$$\hat{\beta}^*_\alpha = \begin{cases} \hat{\beta} & \text{if } \mu > f_\alpha \\ \hat{\beta}^* & \text{if } \mu \leq f_\alpha \end{cases},$$

where μ is the usual likelihood ratio statistic and f_α represents the α-level critical point of the F-distribution with $(K - r)$ and $(T - K)$ degrees of freedom.

Because of the difficult distribution theory arising from the adoption of preliminary test estimation, the comparison of OLS and the PTPC estimators under the "strong" MSE norm previously discussed is not addressed. Instead the usual risk function used in this literature is the squared error loss $E(\beta - \tilde{\beta})'(\beta - \tilde{\beta})$, where $\tilde{\beta}$ denotes an arbitrary estimator of β. Straightforward adaptation of the results in Bock, Yancey, and Judge leads to the sufficient condition for the PTPC estimator to be superior to the OLS estimator, namely that

$$(6)\quad \psi = \sum_{i=r+1}^{K} (\lambda_i\delta_i^2/2\sigma^2) \leq \frac{1}{4}\left(\lambda_K \sum_{i=r+1}^{K} (1/\lambda_i)\right)$$

where ψ represents the noncentrality parameter of μ.

In light of condition (6), it is evident that the argument to use MSE testing for selecting a PC estimator when the components are not interpretable only delays by one analytical step the same results of restricted least squares under erroneous constraints. The dilemma of unknown population parameters cannot be circumvented by preliminary testing in the absence of a priori information on the PC regression model.

Conclusion

In this paper we have provided a summary of some of the analytical results currently available on principal components regression. These results follow immediately from the identification of the implied restrictions on the original parameter space. The deletion of principal components associated with "small" characteristic roots generates biased parameter estimates with smaller sampling variances than OLS. Whether there is an MSE gain relative to OLS using this procedure depends upon the severity of the collinearity and the relationship the deleted components bear to the dependent variable. Deletion of a component strongly related to the dependent variable may induce substantial bias.

When components are deleted on the basis of statistical tests, the RLS formulation of PC regression combined with the PT literature make it clear that any testing procedure may not produce parameter estimates superior in MSE relative to OLS. The superior MSE estimator among OLS, PC, and PTPC estimators depends on the value of ψ, the noncentrality parameter of the test under consideration. Hence, preliminary test selection of principal components does not circumvent the dilemma

1, . . . , K are the columns of X, equals the zero vector, or nearly so. Since $A'X'XA = \Lambda$, $\Lambda = \text{diag}(\lambda_1, \lambda_2, \ldots, \lambda_K)$ and $a'_j X' X a_j \simeq 0$, for say $j = r + 1, \ldots, K$, if the last $(K - r)$ characteristic roots are small, the linear combinations, $Xa_j \simeq 0$ define near exact multicollinearities that exist in X.

The effect of multicollinearity is readily seen when the OLS estimates are expressed as $\hat{\beta} = (X'X)^{-1}X'y = \sum_{i=1}^{K} \lambda_i^{-1} a_i z'_i y$ with covariance matrix $\sigma^2 (X'X)^{-1} = \sigma^2 \sum_{i=1}^{K} \lambda_i^{-1} a_i a'_i$. If the moment matrix $X'X$ has one or more characteristic roots which are relatively small then individual OLS estimates and variances can become large, thus yielding only imprecise information on β. In situations where multicollinearity is severe, OLS produces unbiased estimators at a potentially high cost in estimator variability and investigators often find it advantageous to consider alternative estimation procedures.

Alternative estimators may be evaluated under norms based upon MSE. The "strong" MSE matrices (see Wallace for the origin of this and other MSE terminology) for the OLS and PC estimators are

$$(3) \quad MSE(\hat{\beta}) = E(\beta - \hat{\beta})(\beta - \hat{\beta})' = \sigma^2 A \Lambda^{-1} A', \text{ and}$$

$$(4) \quad MSE(\hat{\beta}^*) = E(\beta - \hat{\beta}^*)(\beta - \hat{\beta}^*)' = \sigma^2 A_1 \Lambda_1^{-1} A'_1 + A_2 \delta_2 \delta'_2 A'_2,$$

respectively. It follows directly from the developments of Toro-Vizcarrondo and Wallace [equation (19)] that a necessary and sufficient condition for $MSE(\hat{\beta}) - MSE(\hat{\beta}^*)$ to be positive-semidefinite is that

$$(5) \qquad \sum_{i=r+1}^{K} \lambda_i \delta_i^2 < \sigma^2,$$

where r is the number of retained components. As is usual with such existence theorems, the condition for the superiority of PC estimators is dependent upon the unknown population parameters of the model, β and σ^2. This theorem does, however, make explicit the concern of Massy that dropping a component associated with a small characteristic root can reduce estimator variability substantially, but if the component is also strongly related to y (in the sense that its coefficient δ_i is large), its deletion can also lead to the introduction of substantial estimator bias.

Potential losses due to bias upon the adoption of PC estimators are typically unknown a priori as the above theorem illustrates. However, the methodology of principal components regression analysis can be useful when examining the potential value of a priori information in dealing with multicollinearity. PC restrictions are known to yield the maximum variance reduction, measured by the sum of estimator variances, of all sets of linear restrictions which are of equal size (see Fomby, Hill, Johnson). Thus the PC restrictions provide a benchmark for the potential relative gain in variance reduction obtainable from the introduction of prior information in the form of linear restrictions on regression coefficients. Potential gains, though not potential losses, from additional introspection are then well defined given the information inherent in PC regression analysis. The calculation of potential variance reduction will be illustrated in section 4.

Alternative Criteria for Component Deletion

Characteristic Root Deletion Criteria

The motivation for deleting principal components associated with very small characteristic values is clear from the discussion. Recall that the covariance matrix for $\hat{\beta}^*$, the PC estimator, is $\sigma^2 \sum_{i=1}^{r} \frac{1}{\lambda_i} a_i a'_i$, where r is the number of components retained. Obviously, the problem of inflated estimator variances is eliminated if only components associated with large λ_i are kept.

A problem exists, of course, in determining when a characteristic root is "small" under a particular set of circumstances. Several authors have attempted to specify "smallness" in one sense or another. In the case of standardized explanatory variables ($X'X$ in correlation matrix form), Pidot suggested that components be deleted when their associated characteristic roots are less than one. His motivation was that such components contribute less to explaining total variation within the data (as measured by tr $X'X = \sum_{i=1}^{K} \lambda_i = K$) than any of the original variables. Equivalently, Pidot's criterion can be thought of as an "average root" criterion where $\sum_{i=1}^{K} (\lambda_i/K) = 1$, and a component should be dropped if its associated characteristic root is less than average in size. Again in the standardized case Jolliffe suggested that a more conservative value of 0.71 might be appropriate. His suggestion resulted from analyzing 587 sets of artificial data and choosing that value which led to the retention of the wrong number of components a minimum number of times.

Such criteria are in general inappropriate (regardless of the value selected) as readily available information concerning relative gains to be obtained from deleting components is ignored. Consider, for example, a two regressor model, where $X'X$ is in correlation matrix form. If the sample correlation between regressors is positive ($\rho > 0$), the variance reduction from deleting the component with characteristics root less than one is $[(1 + \rho)/2] \times 100\%$ of total estimator variance $2\sigma^2/(1 - \rho^2)$. Thus, the

Deletion Criteria for Principal Components Regression Analysis

Thomas B. Fomby and R. Carter Hill

The use of principal components (PC) regression in situations involving ill-conditioned design matrices has been the topic of considerable research in the past few years (see, for example, Farebrother; Greenberg; Gunst and Mason; Hill, Fomby, Johnson; Johnson, Reimer, Rothrock; Lott; Marquardt; and Mittelhammer and Baritelle. The recent paper in this *Journal* by Mittelhammer and Baritelle reviews two popular strategies for choosing principal components to delete in regression analysis. First, a characteristic root criterion is described whereby components associated with small characteristic roots are deleted, the argument being that their elimination implies little loss of total variation present in the independent variables. Second, a t-value criterion is considered in which estimated PC coefficients are tested for statistical significance and components retained or deleted conditional upon the outcome of those tests. Potential mean squared error (MSE) gains, relative to ordinary least squares (OLS) regression, when using these criteria are discussed.

We hope to provide further perspective to the findings of Mittelhammer and Baritelle and others by recasting PC regression into a restricted least squares (RLS) problem. Having done so, the properties of the estimators follow straightforwardly and the usefulness of PC regression is more clearly defined.

The plan of the paper is as follows: first, we recast into its RLS equivalent the PC regression model; next, we briefly discuss multicollinearity, its effects on OLS estimates, and how PC analysis may be expected to aid the researcher; then we examine several criteria and, finally, make our concluding comments.

PC Regression as a RLS Problem

Let the model under consideration be

$$(1) \qquad y = X\beta + \epsilon,$$

where y is a $T \times 1$ vector of observations, X is a $T \times K$ matrix of observations of rank K, β is a $K \times 1$ vector of unknown parameters, and ϵ is a $T \times 1$ vector of $N(0, \sigma^2)$ independent and identically distributed random disturbances. Consider the transformation

$$(2) \qquad y = XAA'\beta + \epsilon = XA\delta + \epsilon = Z\delta + \epsilon,$$

where $A = (a_1, a_2, \ldots, a_K)$ is a $K \times K$ matrix whose columns (a_i) are characteristic vectors of $X'X$. Assume the characteristic vectors are chosen to form an orthonormal set and are ordered to correspond to the relative magnitudes of the characteristic roots of the positive definite matrix $X'X$. The $T \times K$ matrix of principal components is $Z = (z_1, \ldots, z_K)$ with $z_i = Xa_i$ being the ith principal component and $z'_i z_i = \lambda_i$ being the ith largest characteristic value of $X'X$.

It has been shown elsewhere (Johnson, Reimer, Rothrock) that the PC estimator obtained by deleting one or more of the variables z_i, applying OLS to model (2) and making the transformation back to the original parameter space is equivalent to a certain RLS estimator. If A is partitioned as $\{A_1 \vdots A_2\}$ where A_2 contains characteristic vectors associated with the deleted components, say Z_2, then the PC estimator is equivalent to the RLS estimator obtained by estimating model (1) subject to the restrictions $A'_2\beta = \mathbf{0}$. These estimators, apart from preliminary test considerations, are known to have smaller sampling variances than OLS estimates but to be biased unless the restrictions are in fact true (see Goldberger and Toro-Vizcarrondo and Wallace).

Identifying the RLS equivalent of the PC estimator has several advantages. First, one is reminded that data reduction techniques impose restrictions upon the associated parameter space which are sample specific. Second, explicit recognition of the restrictions permits an evaluation of their theoretical implications. Finally, the RLS formulation is a convenient vehicle for statistical investigation of the partitioning of Z.

Multicollinearity and PC Regression Existence Theorem

While the effects of multicollinearity on OLS estimates are well known, it will be useful to consider the problem briefly. Following Silvey, multicollinearity is said to exist if there are constants c_1, c_2, $\ldots$, c_K, not all zero, such that $\sum_{i=1}^{K} c_i x_i$, where x_i, i

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Multiple Controlled Experimental Factors

A generalization to more than two feed components leads to similar conclusions about the role of isoquants and their higher dimensional equivalents. A cattle-feeding experiment slightly more complicated than that reported in Heady, Roehrkasse, Woods, Scholl, and Fuller would illustrate a generalization to three feed components. In addition to soilage and corn, suppose a standardized protein supplement were blended into the ration. Then the two experimental factors would be any pair of percentages by weight of the three feed components, say percentages of protein supplement and corn.

Under the same assumptions that make the economic problem static, so that we simply have to minimize feed cost for a specific gain level, the empirical relationships required are

$$x = f(r,s), \tag{21}$$

$$y = g(r,s), \text{ and} \tag{22}$$

$$z = h(r,s), \tag{23}$$

where x, y, and z are mean pounds of the three feed components consumed in achieving a specified level of gain when the percentages of the ration comprised of protein supplement and corn are r and s. The above three equations are a generalization of (1) and (2) for the one-factor experiment. The feed cost equation is

$$FC = P_x x + P_y y + P_z z, \tag{24}$$

where P_x, P_y, and P_z are the prices for feed components.

If we substitute (21), (22), and (23) into (24), the economic decision variables are r and s, percentages of protein supplement and corn in the ration, a good choice for practical decisions in the author's opinion. But we can replace r and s with x and y as variables in the cost function of (24) if these two variables were considered better than r and s for some reason. This would be comparable to replacing R by S in the swine-feeding experiment.

We can view (21), (22), and (23) as a parametric representation of a functional relationship between z and the two independent variables x and y. For every pair of values (r,s) there is a corresponding triple of values (x,y,z), the locus of which implies a function

$$z = \psi(x,y), \tag{25}$$

a three-dimensional generalization of an isoquant. Using x and y as economic decision variables and substitution of (25) for z in (24) gives a cost-minimization criterion function which yields the classic results of production economics as necessary conditions:

$$P_x/P_z = -\partial z/\partial x \text{ and } P_y/P_z = -\partial z/\partial y. \tag{26}$$

The above two equalities of price ratios and marginal rates of substitution are one of the independent pairs, out of a total of three pairs, which define constrained cost minimization in the theory of the firm. We should not neglect second order conditions and the possibility of a boundary solution to the cost-minimization problem, especially in view of Brokken's results.

The statistical estimation problem is essentially unchanged. An identity exists among the three variables x, y, and z for a given pair of values for r and s. Therefore, one out of the three equations in (21) through (23) is deleted in statistical estimation, and the omitted equation is given by the identity applied to the estimated functions in r and s.

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of unknown population parameters that is so commonly associated with existence theorems on biased estimation.

Finally, the primary usefulness of PC regression lies in its function as an exploratory tool. It can serve to identify multicollinearities in the data, suggest useful data transformations, and provide a variance reduction benchmark. If, however, coefficient estimates based upon PC regression are to be adopted, potential losses due to estimation bias should be judged in light of the available a priori information in each application. If no such information is available pretesting is not likely to provide "better" parameter estimates than OLS. In the face of such uncertain prior information the investigator may do well to consider a Stein-like estimator as described by Berger or Bock which are known to dominate OLS in squared error loss if certain conditions are met.

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Estimating Irreversible Supply Functions

Bruce Traill, David Colman, and Trevor Young

The question of specifying and estimating irreversible functions has arisen most frequently in the context of agricultural supply. Theoretical arguments in favor of an asymmetric response of output to rising and falling prices were advanced by Johnson. A number of authors have attempted to estimate such relationships (Hartman, Houck, Saylor, Tweeten and Quance 1969). In this paper, we argue that the general lack of success of these studies is the result of a misunderstanding of the nature of the supply irreversibility. An alternative method of segmenting the price series is proposed and an empirical example presented.

Empirical Methods of Segmenting the Price Series

The most popular method of partitioning to allow estimation of a nonreversible function was proposed by Wolffram in his criticism of a dummy variable approach employed by Tweeten and Quance (1969). Essentials of Wolffram's technique are clearly described in a recent note by Houck. The equation to be estimated is $Q_t = \beta_0 + \beta_1 WR_t + \beta_2 WF_t + \epsilon_t$, where WR_t is the sum of all period-to-period increases in expected price (P^*_t) from its initial value up to period t; WF_t is the sum of period-to-period decreases in P^*_t. In Wolffram's presentation, the variable WF_t is positive rather than negative as above. In Houck's presentation, the dependent variable is $Q_t - Q_0$ (Q_0 being the quantity in the first period). It is, of course, anticipated that the estimated response of output to a rise in price ($\hat{\beta}_1$) would be greater than the response to a fall in price ($\hat{\beta}_2$).

Our criticism of the Wolffram technique in supply response studies is its implication that for given starting and finishing prices, the greater the price changes in the intermediate period, the larger is output at the end of the period.[1] Most economists would probably argue that given a high correlation between price variability and uncertainty (uncertainty being unexpected variability), highly variable prices would lead to a reduction in output due to risk considerations. It is possible that the generally poor empirical results obtained when trying to estimate nonreversible supply functions using this form may be attributed to the unrealistic pattern of supply response implied by the model, rather than to multicollinearity between the price series as suggested by some authors (Houck, Saylor).

The Modified Wolffram Method

Johnson's work on asset fixity provides the main theoretical justification for the irreversible supply relationship and implies a pattern of response dissimilar to that posited by Wolffram. According to Johnson's theory, changes in the use of an input as the price of the final product varies can be represented by a step function, but one in which the step part of the function always moves to the point of existing factor use. This results from a divergence between the acquisition cost of an input and its salvage value. Figure 1 shows the resulting two supply curves (AC and SV respectively) for an input (I). Starting from the point a where the marginal value product (MVP) of the input is equal to its acquisition cost at an expected product price of P^*_0, an increase in product price would shift the factor demand curve to the right along AC, increasing factor use. However, in the reverse direction, factor use would not fall until the input's demand curve intersected SV to the left of point b (at P^*_1 in the diagram) when factor use would also become elastic in the downward direction. What is important, in view of the current discussion, is that following a product price fall from P^*_0 to P^*_1, price would have to rise back beyond P^*_0 before input use would again become elastic. As the factor use and product supply functions are closely related through the production function, it is reasonable to represent product supply as a similar step function.

For empirical purposes, it is assumed that the elastic portion of the curve in response to falling prices is unimportant (i.e., that prices do not fall sufficiently to warrant disposal of large fixed assets). Then, following a fall in price and movement

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[1] As Houck shows, WR_t can be written as $\sum_{i=1}^{t} \Delta PR^*_i$ and WF_t as $\sum_{i=1}^{t} \Delta PF^*_i$ where $\Delta PR^*_i = P^*_i - P^*_{i-1}$ if $P^*_i > P^*_{i-1}$ and $= 0$ otherwise; $\Delta PF^*_i = P^*_i - P^*_{i-1}$ if $P^*_i < P^*_{i-1}$ and $= 0$ otherwise. Also, note from table 1 that $WR_t + WF_t = P^*_t - P^*_0$ where P^*_0 is expected price in the initial period. Then if $Q_t = \beta_0 + \beta_1 WR_t + \beta_2 WF_t$ and $P^*_t - P^*_0 = WR_t + WF_t = K$ (some given difference between starting and finishing prices), $Q_t = \beta_0 + \beta_1 WR_t + \beta_2 (K - WR_t) = \beta_0 + (\beta_1 - \beta_2)WR_t + \beta_2 K = \beta'_0 + (\beta_1 - \beta_2)WR_t$ (where $\beta'_0 = \beta_0 + \beta_2 K$). Thus the larger the sum of positive price changes (and consequently the larger the sum of negative price changes in absolute terms), the larger WR_t and the larger Q_t, given that $(\beta_1 - \beta_2) > 0$.

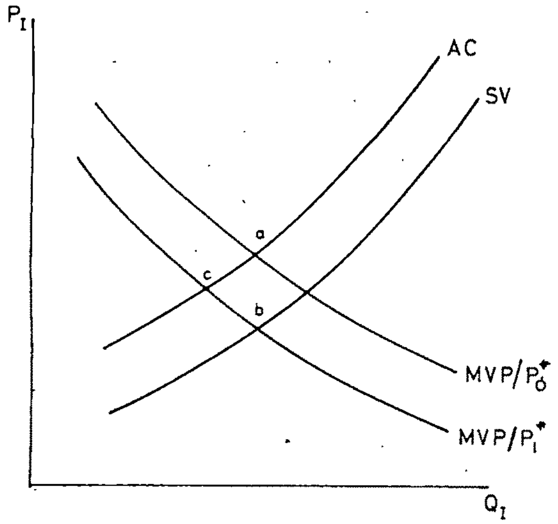

Figure 1. Asset fixity

down the inelastic portion of the supply function, price must regain its previous high level before response becomes elastic. We thus obtain a ratchet model. It can be represented easily by a simple modification of the Wolffram method; when price rises but remains below its previous high level, the amount of the price change is added to the price fall series (MWF_t) rather than to the price rise series (MWR_t). Table 1 and figure 2 provide a comparison of the Wolffram and Modified Wolffram variables and output implications for hypothetical expected price series and supply equations.

It should be noted that in the Modified Wolffram, the coefficient of MWR_t no longer represents the response of output to every price rise, but the response to a price rise beyond the previous maximum. The coefficient of MWF_t shows the response of output to price movements in either direction below the historical high. Estimating the equation $Q_t = \beta_0 + \beta_1 MWF_t + \beta_2 MWR_t + \epsilon_t$ is equivalent to estimating $Q_t = \alpha_0 + \alpha_1 P^*_t + \alpha_2 P^{*\,max}_t + \epsilon_t$, where

Table 1. Wolffram and Modified Wolffram Methods of Segmenting the Price Series and Their Output Implications

Time (t)	P_t	WR_t	WF_t	WQ_t[a]	MWR_t	MWF_t	MWQ_t[b]
1	9	0	0	20	0	0	20
2	14	5	0	30	5	0	30
3	7	5	−7	23	5	−7	23
4	4	5	−10	20	5	−10	20
5	11	12	−10	34	5	−3	27
6	9	12	−12	32	5	−5	25
7	14	17	−12	42	5	0	30
8	16	19	−12	46	7	0	34
9	11	19	−17	41	7	−5	29
10	18	26	−17	55	9	0	38

[a] Employing the equation $WQ_t = 20 + 2\ WR_t + WF_t$.
[b] Employing the equation $MWQ_t = 20 + 2\ MWR_t + MWF_t$.

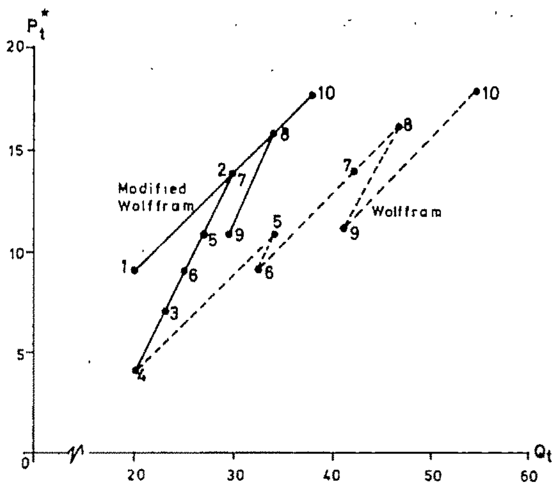

Figure 2. Hypothetical response over time: Wolffram and Modified Wolffram models

$P^{*\,max}_t$ is the previous maximum expected price. $\beta_1 = \alpha_1$ and $\beta_2 = \alpha_1 + \alpha_2$.

Empirical Application

The Modified and original Wolffram methods have been used in an acreage response model of the United States Late Summer Onion crop. This crop comprises 70% of total U.S. output and its production is rather specialized; it is likely that asset fixity is important and that improved estimates of the supply relationship may be obtained using an asymmetric response function.

Previous attempts to model the onion industry by Chen, Jesse, Peck, and Saad have concluded that there is no major substitute for onions warranting inclusion in a supply model. These authors have had to rely on a specification using some combination of lagged prices, lagged acreage, and a trend variable as their regressors.

Specifying price expectations for the asymmetric models poses something of a problem. Whereas with a reversible function expectations can be formulated as a weighted sum of past prices and estimated within the model using a distributed lag specification, the asymmetric response models require prior knowledge in order to segment the series into rising and falling expected prices. All past authors have assumed that $P^*_t = P_{t-1}$, and we adopt the same convention in constructing our price series.[2]

Regression results are shown in table 2. For each of the three methods (symmetric, Wolffram, and Modified Wolffram), equations with and without a lagged dependent variable in addition to the price expectations variables are presented. Time trends

[2] A fuller version of this paper which contains details of the original and constructed data is available, on request, from the authors.

Table 2. Alternative Methods of Segmenting the Price Series Applied to Acreage Response of the Late Summer Onion Crop 1952–74

								S.R. Elasticity w.r.t.					
Equation	Constant	A_{t-1}	P_{t-1}	WR_t	WF_t	MWR_t	MWF_t	Price Rise Variable	Price Fall Variable	R^2	d	h	t
1	54.971		1.897					.102	.102	.259	.789		
	(22.926)		(2.709)										
2	12.737	.689	1.957					.105	.105	.566		.428	
	(1.120)	(3.766)	(3.563)										
3	55.342			1.520	.956			.082	.052	.530	.830		3.399
	(39.398)			(2.612)	(1.523)								
4	23.523	.538		1.666	1.257			.090	.068	.699		.466	2.888
	(2.393)	(3.259)		(3.469)	(2.379)								
5	47.215					6.420	1.622	.345	.087	.441	.950		2.549
	(9.806)					(3.414)	(2.562)						
6	−9.950	.861				8.215	1.591	.442	.086	.894		−.923	7.651
	(−1.484)	(9.002)				(9.506)	(5.621)						

Note: Variable definitions are dependent variable, 1000 acres planted (mean = 61.217); A_{t-1}, Lagged acreage; P_{t-1}, the lagged Late Summer average price received by farmers in \$/cwt. deflated by an index of prices paid by farmers for all production items (mean = 3.292). Other variables are as defined in the text; d is the Durbin-Watson statistic; h is Durbin's h statistic; t is the calculated value of the statistic to test the null hypothesis of equality of price rise and fall coefficients. Figures in parentheses are t-ratios.

were also fitted, but these improved only the reversible function and are not presented here.

The symmetric function, despite a low R^2, yields reasonable results in terms of signs, magnitudes, and significance of coefficients when lagged acreage is included. The Wolffram method (equations 3 and 4) provides statistically, significantly different price rise and fall coefficients and a reasonable improvement in R^2. These results normally would be interpreted as supporting the hypothesis of nonreversibility; yet, the magnitude of the difference between price rise and fall coefficients is rather small (as Houck found for milk) and the elasticity of response in both directions is less than for the reversible model. By contrast, the magnitude of the difference between the coefficients for the Modified Wolffram model is large—the response to a price rise above the previous maximum being about four times as large as the response to price changes below the maximum. This is mainly as a result of an increase in the price rise coefficient as opposed to a decrease in the price fall coefficient.

Concluding Remarks

We believe that there is a strong case for estimating nonreversible supply functions for many commodities, but reiterate that methods previously employed to segment price variables do not reflect the response of production to prices in a realistic manner. The proposed Modified Wolffram model is more accurate theoretically, and in an empirical application to the Late Summer onion crop, indications are that the difference in short-run response to price changes above and below the previous maximum price may be much larger than indicated by the ordinary Wolffram model.

There are, however, two remaining matters deserving a mention. First, asset fixity, the source of asymmetry, is a short-run phenomenon. In the long run, as fixed assets wear out, they are not replaced if their marginal value product is below their acquisition cost—thus c is a long-run equilibrium at price P^*_1 in figure 1, implying a symmetric long-run supply function. In order to permit an empirical model to display asymmetric short-run but symmetric long-run response, an Almon lag could be applied to each price series (as opposed to the geometric lag of table 2, which imposes unequal short- and long-run responses). The following equation was fitted to the onion data:

$$\begin{aligned} A_t = {} & \underset{(12.633)}{49.139} + \underset{(1.838)}{4.069}\, MWR_t \\ & + \underset{(2.060)}{4.287}\, MWR_{t-1} \\ & + \underset{(3.519)}{2.064}\, MWF_t + \underset{(3.705)}{1.934}\, MWF_{t-1} \\ & + \underset{(1.908)}{0.993}\, MWF_{t-2} + \underset{(1.616)}{.870}\, MWF_{t-3}. \end{aligned}$$

$$R^2 = 0.741,\ d = 0.983,\ t = 1.591$$

The equation indicates that the full response to price rises above the previous maximum (associated with new investment) takes about two years, whereas the response to price changes below the maximum (associated with disinvestment) covers four years. The long-run responses to MWR and MWF are respectively 8.356 and 5.681 and testing the hypothesis that these are equal yields a t-value of only 1.591.

Second, not only may the expected price of the commodity under consideration be important in determining its production, but also the expected price of substitute (or complement) commodities. If

we postulate $Q_{1t} = f(P^*_{1t}, P^*_{2t})$, partitioning only P^*_{1t} would be inappropriate. A sensible solution would be to enter the two prices as a ratio and segment the ratio according to whether P^*_{1t}/P^*_{2t} is greater or less than P^*_{1t-1}/P^*_{2t-1}. In our view, multiple commodity substitution, which could not be handled in this manner, is unlikely to be compatible with the existence of supply irreversibility; where there is ready substitution in supply, commodities are likely to share fixed assets and the response to a change in relative prices is merely a reallocation of resources towards the more profitable enterprise.

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Price, Income, and Foreign Exchange Reserve Elasticity for Asian Rice Imports

Badrul Islam

The immense socioeconomic and political influence of rice and its importance in international transactions has induced governments in Asian rice deficit countries to intervene in foreign and domestic trade. Rice imports are a government monopoly in almost all the Asian rice-importing countries, except Hong Kong, Malaysia, and Singapore. Even in these three countries imports are regulated by a number of other measures.

This paper develops the hypothesis that a significant proportion of government interference in rice importing is motivated by a desire to conserve foreign reserves. On the basis of this theory, we derive an import demand function which has foreign reserves, price, income, and domestic production as independent variables. Others have mentioned foreign reserves as a determinant of rice imports. For example, Ridler and Yandle comment that "in some developing countries, balance of payment difficulties continue to be a limiting factor in authorisation of rice imports" (p. 55). Finally, the import demand functions with annual data for six Asian countries are fitted. In general, our empirical results support the theory.

Overall Theory

We hypothesize that rice imports for a typical Asian country depend partly on variables termed "desired imports" and "government-determined imports." Desired imports (M^*) reflect internal pressures of demand and will be defined in such a way that actual imports (M) equal desired imports when the country is not experiencing foreign exchange shortages. However, when the country is experiencing foreign exchange shortages, levels of imports are below M^* and dominated by the variable G, government-determined imports. Thus, we hypothesize that the relative influence of M^* and G upon M depends on foreign exchange reserves F, which reflect the country's capacity to import. When F is high, M will be determined basically by M^*, but if F is low G will determine M. The rationale here is that the government varies restrictions on rice imports inversely with the country's capacity to import, and this capacity is reflected by the country's foreign exchange reserves. Algebraically, we express our theory as follows:

$$M = \alpha_1 M^* + \alpha_2 G, \tag{1}$$

Where the coefficients $\alpha_1 = f_1(F)$, and $\alpha_2 = f_2(F)$ are defined so that as F increases, α_1 approaches unity, and α_2 approaches zero. The particular functional forms adopted are

$$\alpha_1 = \left(1 - \frac{a}{F}\right) \text{ and } \alpha_2 = \frac{a}{F}, \tag{2}$$

where the parameter $a > 0$ determines the rate of change of α_1 and α_2 with respect to F. Equation (2) implies that as F increases, α_1 increases at a decreasing rate. The coefficient α_1 is between 0 and 1 for all $F \geq a$.

Desired Imports

Desired imports at time t are the quantity of rice that a country would import if it did not experience foreign exchange shortages. They are defined as

$$M^*_t = C^*_t - Q^*_t, \tag{3}$$

where M^*_t denotes desired imports, and C^*_t and Q^*_t are the desired levels for rice consumption and production, i.e., the levels in the absence of foreign exchange shortages. (Suitable data were not available to allow us to consider changes in inventories.) It is assumed that actual production, Q_t, is independent of foreign reserves; thus, $Q_t = Q^*_t$. The assumption is that policies of domestic price support or subsidy which affect actual rice production (but are mostly pursued in the developed countries) are not aimed at conserving foreign exchange but at supporting domestic farm income or achieving self-sufficiency for sociopolitical or other economic reasons. For example, Japan and the United States support domestic rice prices to boost farm income. We assume, therefore, that at least in the short run, the only way that changes in a country's foreign exchange reserves can affect rice imports is by their influence on consumption.

Let desired consumption be defined by

$$C^*_t = X^*_t N_t, \tag{4}$$

where X^*_t denotes per capita desired consumption

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While absolving them of any responsibility, the author is nonetheless grateful to Peter Dixon and Peter Warr for helpful comments on previous drafts of this paper.

and N_t is total population. Per capita desired consumption is not a directly observable variable. It can be measured indirectly by projecting consumption from a base period using observable variables thought to affect X^*_t. Following the tradition of FAO and others involved in food demand projections (for example, see FAO; Blakeslee, Heady, Framingham; OECD), we project per capita desired consumption on the basis of per capita real income. (Among other variables which might be considered is the price of rice. However, empirical studies suggest that Asian rice consumption is not sensitive to price changes. Canterbery and Bickel find that for almost all Asian countries, price elasticity of demand is close to zero. Studies on marketable surplus of subsistence farmers have shown that producers' rice consumption is insensitive to price changes, e.g., see Toquero, et al.) A double-log consumption function describing the relationship between desired per capita consumption and real income is used,[1] i.e.,

$$(5) \qquad X^*_t = \beta Y_t^{\eta}, \text{ and } X^*_t = X^*_0(Y_t/Y_0)^{\eta},$$

where Y_t is the per capita real income, β and η (the income elasticity of consumption) are parameters, and 0 denotes the base period. Y_t and Y_0 are observable variables and the estimates of η are available from other sources. Therefore, we can calculate X^*_t if the base period per capita desired consumption (X^*_0) is known. Base period desired consumption should equal the observed consumption (X_0) if the country has not suffered from foreign exchange shortages in the reference period. Hence, the period in which the country had highest foreign exchange reserves (or highest capacity to import) is chosen as the base period, and for the base period it is assumed that $X^*_0 = X_0$.

Using the above results, an operational formula for M^*_t is obtained,

$$(6) \qquad M^*_t = N_t X_0(Y_t/Y_0)^{\eta} - Q_t.$$

Government-Determined Imports

Assume that government-determined imports, G, respond to desired imports, M^*, and to the foreign currency import price of rice, P. The adopted functional form is

$$(7) \qquad G_t = \gamma_0 + \gamma_1 M^*_t + \gamma_2 P_t,$$

where γ_0, γ_1, and γ_2 are parameters. In times of severe foreign exchange shortage (i.e., when the determination of M is dominated by G) we expect that if a country's desired imports increase, then its government-determined imports will increase. That is, even at times when the preservation of foreign exchange is a central concern of government policy, it is expected that governments will allow some flexibility in the import volume of rice to accommodate changes in the internal pressure of demand. However, it is likely that government efforts to preserve foreign exchange will allow only partial satisfaction, through imports, of increases in demands for rice. Consequently, we expect that $0 < \gamma_1 < 1$. The expected sign for γ_2 is negative. A government, when trying to preserve foreign exchange, is likely to reduce the import volume of rice in response to an increase in the international currency price. There is no prior expectation on the sign of γ_0.

Estimation, Results, and Conclusions

The estimating equation based on the theoretical development from the previous sections is

$$(8) \quad M_t - M^*_t = a\gamma_0(1/F_t) + a(\gamma_1 - 1)(M^*_t/F_t) + a\gamma_2(P_t/F_t) + u_t,$$

where M^*_t is measured according to equation (6) and the expected signs for the coefficient are given by: $a(\gamma_1 - 1) < 0$ for $a > 0$, and $1 > \gamma_1 > 0$; and $a\gamma_2 < 0$ for $a > 0$, and $\gamma_2 < 0$. The additive error terms u_t are assumed to be identically distributed normal random variables with zero mean and finite variance.

Equation (8) was estimated by ordinary least squares with annual data for six Asian countries for the period 1953–72. Estimated values of the coefficients, the coefficient of determination (R^2), the Durbin-Watson statistics (DW), and the data sources are given in table 1. Elasticities at the mean values of the variables are in table 2. These elasticities were calculated according to the following formulas, omitting the t subscripts.

Price elasticity. Using (8), we obtain

$$\frac{\partial M}{\partial P}\frac{P}{M} = \left[1 + \frac{a(\gamma_1 - 1)}{F}\right]\frac{\partial M^*}{\partial P}\frac{P}{M} + \frac{a\gamma_2}{F}\frac{P}{M}.$$

Then from (6), we have $\frac{\partial M^*}{\partial P} = -\eta_Q \frac{Q}{P}$, where η_Q is the price elasticity of domestic supply. Thus, the price elasticity of demand for imported rice is:

$$(9) \quad \frac{\partial M}{\partial P}\frac{P}{M} = -\left[1 + \frac{a(\gamma_1 - 1)}{F}\right]\eta_Q\frac{Q}{M} + \frac{a\gamma_2 P}{FM}.$$

The estimates of η_Q used in calculating the price elasticities are listed in table 2.

Income elasticity. Differentiating equation (8), gives

$$\frac{\partial M}{\partial Y}\frac{Y}{M} = \left[1 + \frac{a(\gamma_1 - 1)}{F}\right]\frac{\partial M^*}{\partial Y}\frac{Y}{M}.$$

Assume that $\partial Q/\partial Y = 0$, and, therefore, from (6) it follows that

$$\frac{\partial M^*}{\partial Y} = \eta N X_0\left[\frac{Y}{Y_0}\right]^{\eta}\frac{1}{Y} = \frac{\eta C^*}{Y}.$$

[1] In food demand projections economists generally use one of the following functions: double log, semi-log, or log inverse. However, for small changes in real income the choice of functional form is not very important (OECD, p. 78).

Table 1. Estimates of the Coefficients

Country	$a\gamma_0$	$a(\gamma_1 - 1)$	$a\gamma_2$	R^2	DW
India 1953–70	741855	−601[a]	8800	.9603	1.5124
Korea 1955–72	39191	−132[a]	−309	.6872	1.7801
Malaysia 1955–72	81762	−209	−69	.1749	1.2977
Pakistan 1953–79	150271	−237[a]	−1003	.8271	1.7763
Philippines 1953–70	72686	−109[a]	−537	.5285	2.0865
Sri Lanka 1953–70	14869	−0.6241	−187[a]	.4178	2.2419

Data sources: Rice production and population data were obtained from issues of the FAO *Production Year Book;* trade data were taken from various issues of the FAO *Trade Year Book.* Nominal income (in domestic currency), consumer price indexes, and foreign exchange reserves (in U.S. dollars) were obtained from issues of the IMF *International Financial Statistics.* The international price of rice was the weighted average f.o.b. export price (in U.S. dollars) for Burma, Thailand, and the United States. The estimates of income elasticity of demand for rice (η) needed to calculate the desired rice imports were taken from FAO 1971, vol. 2, table B. The numbers used were India, 0.40; Korea, .30; Malaysia, .19; Pakistan, .30; Philippines, .20; and Sri Lanka, .40. The base period per capita real income (Y_0) and actual consumption (X_0) were the three-year moving average real income and actual consumption for the period in which the country had highest foreign exchange reserves.

[a] Significant at 99% confidence level.

Hence, the income elasticity of demand for imported rice is

$$(10)\qquad \frac{\partial M}{\partial Y}\frac{Y}{M} = \left[1 + \frac{a(\gamma_1 - 1)}{F}\right]\eta\,\frac{C^*}{M}.$$

Reserve elasticity. Equation (8) implies

$$\frac{\partial M}{\partial F}\frac{F}{M} = -\frac{a\gamma_0}{FM} - \frac{a(\gamma_1 - 1)M^*}{FM} - \frac{a\gamma_2 P}{FM}.$$

All the coefficients in table 1, except for the coefficient of P/F for India, have the right sign. (The coefficient of P/F for India is insignificant even at the 10% significance level. However, a possible explanation for its positive sign may be the fact that India exported superior quality rice and imported inferior quality rice.) The coefficient of determination is lowest in the case of Malaysia. This was expected because rice imports were not a government monopoly in Malaysia and the country did not experience foreign exchange shortages. (For supporting evidence, see Weiskopf 1972.) Our import function was designed to explain imports in the presence of direct government regulation of imports and/or foreign exchange shortages.

Table 2. Elasticities of Imports

Country	Price Elasticity	Income Elasticity	Reserve Elasticity
India	−6.09	10.32	2.48
Korea	−3.35	2.72	1.19
Malaysia	−0.32	0.34	−0.01
Pakistan	−8.17	5.05	4.24
Philippines	−5.31	1.18	1.42
Sri Lanka	−0.82	0.97	0.09

Note: The estimates of η_Q used in calculating price elasticity of imports were as follows: India, .35 (source, UNCTAD); Korea, .326 (Moon); Malaysia, .230 (Arromdee); Pakistan, .35 (UNCTAD); Philippines, .30 (Toquero et al.); and Sri Lanka, .35 (UNCTAD).

Some of the price and income elasticities have larger absolute values than is usual in import demand functions. The average of the six reported price elasticities is −4.0, while for the income elasticities the average is 3.4. According to our theory, rice imports play a residual role. A 1% increase in income, for example, might generate a much less than 1% increase in consumption demand for rice. However, if rice imports are only a small percentage of total consumption, then a small percentage change in consumption can have a large percentage impact on imports. Of the six countries considered here, India had the largest average values for C^*/M and Q/M and, therefore, it is not surprising that India's income and price elasticities of demand for imports are also large in absolute value.

The elasticities of imports with respect to foreign exchange reserves are greater than unity for all the countries except for Malaysia and Sri Lanka. As expected in the case of Malaysia, the one country that did not experience foreign exchange shortages, reserve elasticity is close to zero (−.01). It is also small (.09) for Sri Lanka. This is probably because the major portion of Sri Lanka's rice imports were from China, bartered for rubber. The average reserve elasticity for the five Asian countries constrained by foreign exchange shortages is 1.8.

Positive and high income and reserve elasticities imply that changes in a country's foreign exchange earnings can affect imports in two significant ways. First, *ceteris paribus,* if a country's exports increase, then its per capita income increases, thus inducing higher imports. Second, an increase in exports will lead to higher foreign exchange reserves and, hence, higher imports. This has impor-

tant implications for Asian rice-exporting countries like Burma and Thailand. It suggests that Asian rice surplus countries could benefit by importing non-rice products from the Asian rice-deficit countries. The export of non-rice products by the rice-deficit countries would increase their rice imports, benefiting the rice surplus countries. This study thus provides further evidence for Myrdal's proposition that "much scope exists for advantageous co-operation (i.e., bilateral trade agreements) in agriculture . . . especially between food surplus and food deficit countries" (p. 659).

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Uncertainty and Incentive Effects in Share Contracts

L. Dean Hiebert

Cheung and Sutinen have emphasized the ability of share contracts to disperse risk. However, if both landlords and workers can mix share, fixed rent, and wage contracts, then risk dispersion under share cropping is redundant (Reid 1976). Other works have emphasized the positive incentive effects of share contracts on input decisions where tenant actions are difficult to monitor (Reid 1976, 1977; Stiglitz). The purpose of this paper is to examine the nature of incentive effects and their role in contractual choice under uncertainty.

Two different models are developed. In the first, input decisions must be made at the beginning of the production period before the "state of nature" is known. In the second model, the tenant can choose input levels after the state of nature is known. It is shown that a share contract will be chosen only if an increase in the tenant's share causes expected output to increase. However, in the first model this incentive effect may be either positive or negative. Thus, in this case the presence of incentive effects does not imply unambiguously that share contracts will be preferred. In the second model, the incentive effect is always positive and leads to a preference for share contracts.

Model 1

In Model 1 (following Stiglitz and Sutinen) the landlord maximizes the expected utility of income by choice of contract terms, subject to the constraint that the tenant accept the contract. However, in contrast to Cheung and Sutinen, it is assumed that the landlord cannot stipulate and enforce a set of input levels required of the tenant. (Sutinen states the model in terms of choice of expected output, while the present model is stated in terms of choice of input level. The difference is, of course, not crucial.) In many cases it is difficult for the landlord to monitor the input choices of his share tenant and thus meaningfully specify the input levels in the contractual agreement. If the landlord cannot specify input levels, different contracts will imply different tenant input decisions and incentive effects will be present. The tenant is assumed to choose input levels in order to maximize the expected utility of income. The input choice is made before the random variable representing the state of nature is known. It is assumed that both the landlord and the tenant have the same beliefs regarding the probabilities of various states of nature. Finally, in order to concentrate on the role of incentive effects in contractual choice the landlord is assumed to be risk neutral.

The net income of the tenant may be written as

$$\alpha p f(x)\theta - cx + \beta, \tag{1}$$

while the net income of the landlord is

$$(1-\alpha)pf(x)\theta - \beta, \tag{2}$$

where $\alpha (0 \leq \alpha \leq 1)$ is the tenant's share of the value of output, $\beta (\beta \gtreqless 0)$ is a fixed monetary payment made by the landlord to the tenant, p is product price, f is an increasing concave production function, θ is a random variable representing the state of nature, x is the input level chosen by the tenant, and c is input price. This specification of incomes allows fixed rent and wage contracts as polar cases. If $\alpha = 1$, then the tenant rents land at a fixed rental rate. If $\alpha = 0$, then the landlord hires the worker at a fixed fee. In general, the fixed payment, β, can be positive or negative (see Stiglitz and Sutinen). In this specification input expenses are not shared with the landlord. The results are not altered qualitatively if input expenses are shared in some proportion, with the exception that a so-called "ideal lease" where output and expenses are shared in the same proportion will not be chosen because the incentive effect is negative.

The expected utility of tenant income is

$$E[U(\alpha p f(x)\theta - cx + \beta)], \tag{3}$$

where U is assumed to be increasing and strictly concave ($U' > 0$, $U'' < 0$), indicating that the tenant is risk averse. Given α and β, the tenant chooses an input level in order to maximize expected utility of income. The first order condition for a maximum is

$$E[U' \cdot (\alpha p f'(x)\theta - c)] = 0. \tag{4}$$

The landlord chooses α and β in order to maximize expected net income,

$$(1-\alpha)pf(x)E\theta - \beta. \tag{5}$$

Clearly, however, not all combinations of α and β are feasible. A constraint on the choice of α and β is imposed because the tenant requires an expected utility of net income equal to the expected utility which he can obtain elsewhere:

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(6) $E[U(\alpha pf(x)\theta - cx + \beta[a])] = \bar{U} = \text{constant},$

where $\beta(\alpha)$ is the minimum β given α which maintains expected utility. Differentiating equation (6) with respect to α yields

$$(7)\quad \frac{dEU}{d\alpha} = E\left[U' \cdot \left(pf\theta + \frac{d\beta}{d\alpha}\right)\right] + \frac{dx}{d\alpha}E[U' \cdot (\alpha pf' - c)] = 0.$$

The second expectation is equal to zero by the tenant's first order condition. Solving for $d\beta/d\alpha$ gives

$$(8)\quad \frac{d\beta}{d\alpha} = -\frac{E[U' \cdot pf\theta]}{EU'} < 0.$$

An increase in α allows the landlord to decrease β in order to maintain the attractiveness of the contract offered the tenant.

The first order condition for maximizing the landlord's expected income is

$$(9)\quad -pfE\theta + (1-\alpha)\frac{dx}{d\alpha}pf'E\theta - \frac{d\beta}{d\alpha} = 0.$$

Substituting for $d\beta/d\alpha$ from equation (8) gives

$$(10)\quad (E[U' \cdot pf\theta]/EU' - pfE\theta) + (1-\alpha)\frac{dx}{d\alpha}pf'E\theta = 0.$$

Condition (10) can be examined to determine the circumstances under which the landlord will choose a share contract, $0 < \alpha < 1$. Because the tenant is risk averse, $E[U' \cdot pf\theta]/EU' - pfE\theta = \text{Cov}(U', pf\theta)$ is negative for $\alpha > 0$. Consequently, α must be less than one for the condition to be satisfied. In addition, since $E[U' \cdot pf\theta]/EU' - pfE\theta$ is negative for $\alpha > 0$, $dx/d\alpha$ must be positive for the condition to be satisfied. Thus, a share contract will be chosen only if the incentive effect, $dx/d\alpha$, is positive. This result is similar to those obtained by Berhold and Stiglitz.

The reason for this result is clear. If the incentive effect is positive, the landlord chooses an α greater than zero because an increase in α induces the tenant to increase expected output. However, the landlord stops short of choosing α equal to one because of the risk aversion of the tenant. Only if both parties are risk neutral will α equal to one be chosen. If the tenant does not alter his input decision in response to a change in α so that the incentive effect is equal to zero, then α equal to zero will be chosen.

If both parties are risk averse, again, α equal to one is not chosen. If the incentive effect is equal to zero, a share contract will certainly be chosen. However, a share contract may still be chosen if the incentive effect is negative because of the risk sharing attributes of the contract. Since a share contract is chosen only if the incentive effect is positive, it is of interest to determine under what circumstances this condition is satisfied. Alternatively, under what circumstances would an increase in α induce the tenant to increase expected output?

Different share contracts that yield the same expected utility to the tenant imply different tenant input decisions. This follows because a change in the share rent alters the distribution of net income confronting the tenant and consequently causes him to alter his input choice. This change in input choice can be examined by differentiating the tenant's first order condition with respect to α and solving for $dx/d\alpha$ to obtain

$$(11)\quad \frac{dx}{d\alpha} = -\frac{E[U_{x\alpha} + U_{x\beta} \cdot d\beta/d\alpha]}{E[U_{xx}]},$$

where subscripts denote appropriate partial derivatives. Since U and f are assumed to be concave, the denominator is negative and $dx/d\alpha$ has the same sign as the numerator. The numerator is

$$(12)\quad E[U' \cdot pf'\theta] + E[U'' \cdot (\alpha pf'\theta - c)(pf\theta + d\beta/d\alpha)].$$

The first term arises because the mean income increases as α increases and may be termed a "mean effect." The second term arises because of the presence of risk aversion and may be termed a "risk effect." The mean effect is positive since $U' > 0$. It can be shown that the risk effect is negative.

From equations (4) and (8),

$$(13)\quad \frac{d\beta}{d\alpha} = -\frac{E[U' \cdot pf\theta]}{EU'} = -\frac{pfc}{\alpha pf'},$$

and the risk term can be written as

$$(14)\quad E[U'' \cdot pf(\alpha pf'\theta - c)(\theta - c/\alpha pf')] = E[U'' \cdot (f/\alpha f')(\alpha pf'\theta - c)^2] < 0.$$

The risk term is negative under the assumption of risk aversion, $U'' < 0$. Consequently, the sign of $dx/d\alpha$ depends on the relative magnitudes of the mean and risk effects and may be either positive or negative. The incentive for increasing input levels is positive only if the mean effect outweighs the risk effect.

The interpretation of this result is straightforward. An increase in α increases both expected income and the riskiness of income. An increase in expected income causes x to increase, while an increase in risk causes x to decrease. Hence, the effect of an expected utility preserving increase in uncertainty cannot be determined without additional assumptions.

Model 2

The previous model assumes that tenant input choices must be made before the state of nature is known. In agricultural production, however, some decisions can be made after the state of nature is known. Reid (1977) appears to have such a situation in mind when he mentions the positive incen-

tive effect of a share contract: "Where uncertainty is reduced sequentially over the crop year, and the hurts from bad surprises can be reduced and the gains from good surprises can be enhanced by cooperative changes in production plans, the share incentive for cooperation will make sharecropping preferable. Thus, when complementary factors need to be coordinated in ways difficult or costly to specify in advance or supervise at the time, the modern theory of tenure choice predicts that sharecropping will be preferred" (p. 406). However, Reid does not develop an explicit model of contractual choice to cover this case. The purpose of this section is to provide such a model.

Suppose the tenant can obtain information concerning the value of θ before the choice of x is made. Given θ, the tenant chooses x to maximize net income,

$$\alpha p f(x)\theta - cx + \beta. \tag{15}$$

Let x^*_θ denote the value of x which maximizes (15) given θ. x^*_θ is then implicitly defined by

$$\alpha p f'(x^*_\theta)\theta - c = 0. \tag{16}$$

Differentiating equation (16) with respect to α and solving for $dx^*_\theta/d\alpha$ gives

$$\frac{dx^*_\theta}{d\alpha} = -\frac{f'(x^*_\theta)}{\alpha f''(x^*_\theta)} > 0. \tag{17}$$

An increase in α always causes the tenant to increase x for a given θ. Hence, the expected incentive effect, $E[dx^*_\theta/d\alpha]$, is positive.

At the beginning of the production period before the value of θ is known, the tenant's net income is random. The expected utility of this random income is

$$E\{U(\alpha p f[x^*_\theta]\theta - cx + \beta)\}. \tag{18}$$

As in the previous model, it is assumed that the landlord chooses α and β subject to a constraint which requires that the expected utility of the share contract be equal to what the tenant could obtain elsewhere. Again, it can be shown that $d\beta/d\alpha$ is negative. Differentiating (18) with respect to α gives

$$\frac{dEU}{d\alpha} = E\left\{U' \cdot \left[pf(x^*_\theta)\theta + \frac{d\beta}{d\alpha} + \frac{dx^*_\theta}{d\alpha}(\alpha p f'(x^*_\theta)\theta - c)\right]\right\} = 0. \tag{19}$$

But $\alpha p f' \cdot \theta - c$ equals zero for all θ by equation (16), and so

$$\frac{d\beta}{d\alpha} = -\frac{E[U' \cdot pf(x^*_\theta)\theta]}{EU'} < 0. \tag{20}$$

The landlord chooses α in order to maximize his expected net income,

$$(1-\alpha)pE[f(x^*_\theta)\theta] - \beta(\alpha). \tag{21}$$

The first order condition is

$$-pE[f(x^*_\theta)\theta] + (1-\alpha)pE\left[f'(x^*_\theta)\theta\frac{dx^*_\theta}{d\alpha}\right] - \frac{d\beta}{d\alpha} = 0. \tag{22}$$

Substituting for $d\beta/d\alpha$ from (20) yields

$$(E[U' \cdot pf(x^*_\theta)\theta]/EU' - pE[f(x^*_\theta)\theta]) + (1-\alpha)pE\left[f'(x^*_\theta)\theta\frac{dx^*_\theta}{d\alpha}\right] = 0. \tag{23}$$

As in the previous model, it can be shown that $E[U' \cdot pf\theta]/EU' - pE[f\theta]$ is negative. Hence, the equation is not satisfied for $\alpha = 1$ or $\alpha = 0$, and a share contract is chosen. This simple model confirms Reid's observation concerning choice of contract when input choices can be adjusted after the random state of nature becomes known.

Conclusion

This analysis has shown that the landlord can influence the decision of the tenant by choice of contract terms. As technology becomes more complex, it becomes increasingly difficult to specify (and monitor) the action to be taken in all possible contingencies so that the incentive of the share contract becomes an important consideration. However, such incentive schemes force the tenant to bear a share of the risk even when the landlord is risk neutral. The analysis assumes that the landlord and the tenant possess similar information. If the landlord possesses a comparative advantage over the tenant in information gathering, he may possess better information about the nature of the production process, and a fixed wage contract may be preferable in spite of its large supervision costs.

In summary, this paper has examined incentive effects in models of contractual choice for two polar situations. In the first case decisions must be made before the state of nature is known, while in the second case the decision can be adjusted after the state of nature becomes known. In both situations the incentive effect must be positive for a share contract to be chosen. The incentive effect may be positive or negative in the first case, but is always positive in the second.

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Some Evidence on Weather-Crop-Yield Interaction

J. Roy Black and Stanley R. Thompson

The nature of crop yield variation can have significant effects on agricultural price stability. For instance, during periods when grain reserves are low, prices are determined largely by crop yields which, in the short run, are primarily determined by weather. The identification of a systematic relationship between weather and crop yields would have significant implications for agricultural policy. Thus, the purpose of this analysis is to test for the existence of nonrandom corn, soybean, and wheat yields by examining some relationships between climatological events and crop yields.

Numerous attempts have been made to assess whether crop yields are random. Twenty-five years ago, Foote and Bean examined U.S. corn yields, finding no evidence of nonrandomness. Sharples found that corn yields during the increasing half of both the single and the double sunspot cycle were not significantly different from yields during the remainder of the cycle. Luttrell and Gilbert investigated the alternative hypothesis that crop yields are either random, cyclical, or bunchy. Their statistical analysis showed little evidence of nonrandomness for the period 1866 to 1932. For the period after 1932, however, there was evidence of autocorrelation; this was attributed to the uneven adoption of hybrid seed and the uneven application rates of fertilizer.

Evidence has been reported of regularly occurring cycles in cotton yields and considerable bunchiness in grain sorghum yields (Lin, Hildreth, Tefertiller). Harrison, using national average yield data, tested the hypothesis that corn yields are related to sunspot activity. He suggests lower-than-average yields were associated with low sunspot activity, while higher-than-average yields were associated with high sunspot activity.

Atmospheric Activity and Weather

What is the evidence for cyclical yield patterns? Do "drought" years occur randomly or do they reoccur at regular intervals? Many analysts have suggested a twenty- to twenty-two-year cyclical pattern for yields in the Great Plains and Corn Belt. Palmer, for example, has commented that "an analysis of the meteorological record beginning in 1887 shows a surprising degree of regularity in the occurrence of severe and extreme drouth in the western third of Kansas. Periods of severe drouth occurred in 1894 and adjacent years; 1913, 1934, and adjacent years; and in 1954 and adjacent years. These four regularly spaced occurrences of severe and extreme drouth may be coincidental. However, historical accounts mention exceptional drouth in the early 1870s and early 1850s" (p. 7). Borchert, Thompson (1973), and Willett (1974, 1975) have expressed similar ideas. The existence of a twenty-year weather cycle superimposed upon the double sunspot cycle has also been suggested.

Is there a relationship between the observed drought periods and solar activity? Sunspot activity exhibits cyclical behavior.[1] Three sunspot cycles have been suggested: (*a*) an 11-year cycle (varies from 9 to 14 years); (*b*) a 22-year "double" sunspot cycle (varies from 20 to 26 years); and (*c*) a secular cycle (possibly alternatively 100 and 80 years).

Figure 1, based upon the work of Willett (1974, 1975), depicts the double sunspot cycle as averaged over the period 1870–1970. A 100-year average was selected, in part because it is consistent with the 100-year phase of the alternating 80-, 100-year secular sunspot cycle suggested by Sleeper. Each 11-year cycle, however, does not bear the same relationship with weather. The minor half of the double sunspot cycle (negative polarity) has little relation to the Great Plains and Corn Belt climate, while both minimum and maximum activity appear to be related to a shift in climate during the major half (positive polarity). Climatologists have observed striking differences in the general circulation of the earth's atmosphere from one 11-year period to the next. Periods of drought in the Great Plains and Corn Belt tend to begin near the end of the minor cycle and continue until the peak of the major cycle. Recent major cycles began in 1888, 1912, 1933, 1954, and 1976.

Willett and others suggest, based upon physical relationships and meteorological data, that drought tends to begin two years prior to the beginning of a major cycle and continue through the peak of the major cycle as depicted in figure 1. Thus, for the following statistical analysis, the drought periods

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[1] Sunspots are cool areas on the surface of the sun. They have extremely strong magnetic fields and rotate in pairs across the face of the sun. Sunspot activity exhibits regular cyclical behavior. Two single cycles comprise the double sunspot cycle. Each single cycle is of opposite magnetic polarity and averages about eleven years in length.

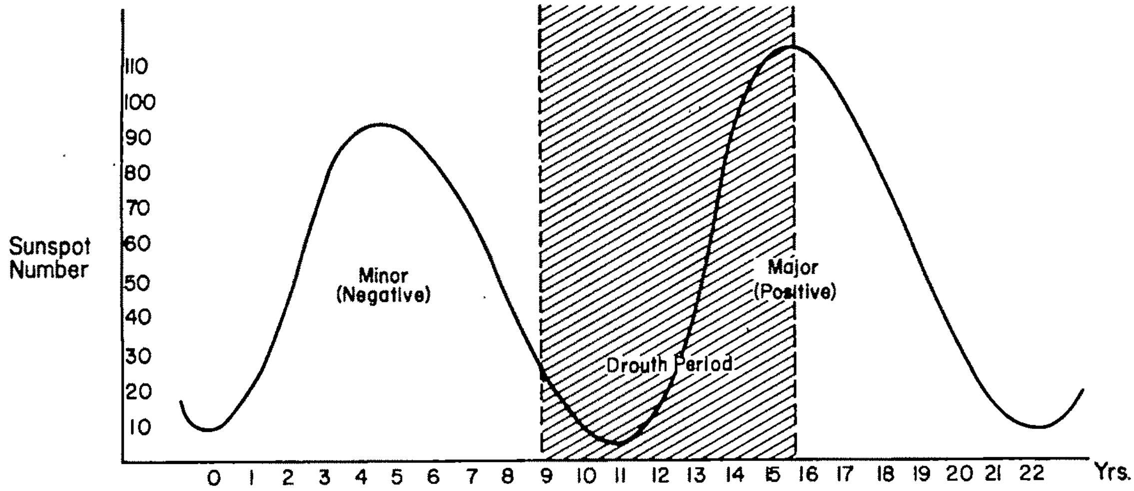

Figure 1. The double sunspot cycle averaged, 1870–1970. Source: Willett, 1975.

were defined as 1865–71, 1887–94, 1910–18, 1932–37, 1952–58, and 1974–present.

Weather and Crop Yield Interaction

Researchers have employed a wide range of statistical techniques to investigate the relationship between drought periods and crop yields. These have generally taken the form of linear regressions of yield against time and the statistical comparison of selected deviations from an average. The hypothesis set forth here is that the functional form of the effect of drought periods on crop yields can be described as a step function. To test this hypothesis, linear models are specified that include a binary variable which takes on the value of 1.0 during drought periods as identified above, and 0 otherwise. Two data series for corn, wheat, and soybeans, although not mutually exclusive, were used. The first set was obtained from McQuigg, Thompson, and LeDuc; the second was U.S. national average yields for corn, 1866–1960; soybeans, 1924–70; and wheat, 1866–1970 (USDA). For the McQuigg data, corn and soybean yield figures are for Iowa, Missouri, Illinois, Indiana, and Ohio; wheat yields are for North Dakota, South Dakota, Nebraska, Kansas, and Oklahoma.

Figure 2 depicts simulated corn yields for Iowa, Missouri, Illinois, Indiana, and Ohio, based upon

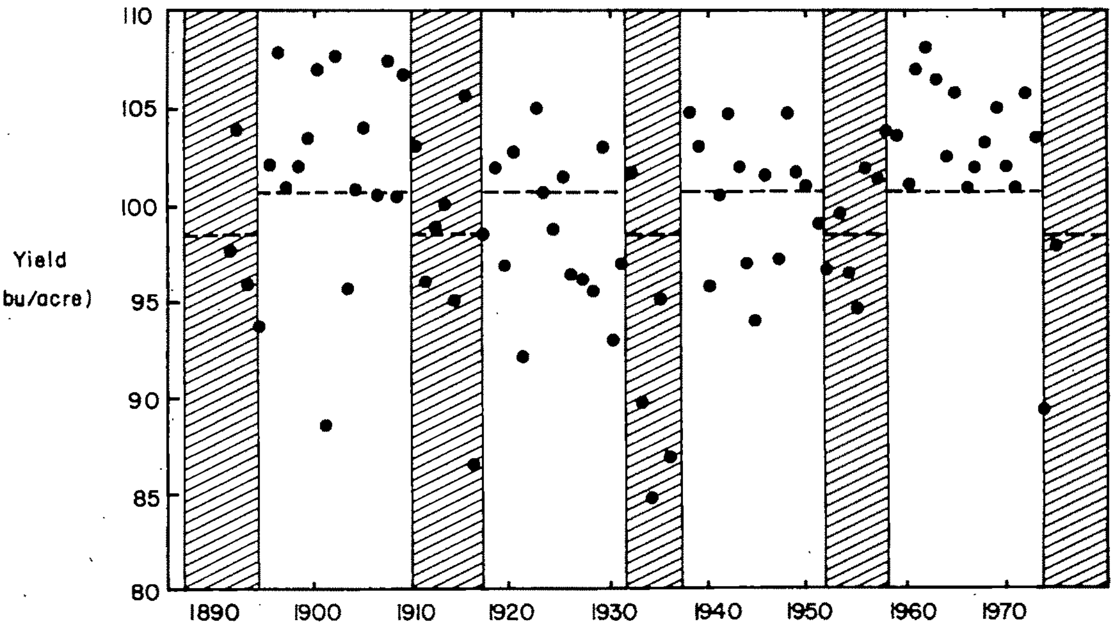

Figure 2. Corn Yields—1973 technology

Table 1. Parameter Estimates for "Drought Cycle" Model for McQuigg, Thompson, and Le Duc Data

Crop	Period	Intercept (bu./acre)	Drought Variable (bu./acre)	R^2	$\hat{\rho}$	Durbin Watson
Corn	1891–1973	101.6	−4.07	.140	NE	2.07
		(162.1)	(3.60)			
Soybeans	1891–1973	30.6	−.67	.061	NE	2.18
		(187.5)	(2.30)			
Wheat	1893–1973	29.4	−1.00	.063	NE	1.63
		(124.8)	(2.30)			
Wheat	1893–1973	29.4	−.75	.082	.2	2.10
		(102.8)	(1.50)			

Note: The autocorrelation parameter (ρ) was not estimated (NE) unless the Durbin-Watson test suggested it might differ from 0; the 95% D_L is 1.59; t values are given in parentheses. The critical t values are $t(.90) = 1.28$, $t(.95) = 1.65$, and $t(.99) = 2.33$.

the work of McQuigg, Thompson, and LeDuc. The authors, a team of agronomists and climatologists, adjusted yields for the period 1891–1973 to "1973 technology," using the framework of Thompson (1969a, b, 1970). Information used in the simulation included meteorological data, selected traditional inputs such as fertilizer, and use of trend variables to pick up general patterns of change. The years within the cross-hatched areas of figure 2 are the "drought" periods identified earlier. The 1974, 1975 observations are our estimates.

The parameter estimates of the drought cycle model, using the McQuigg data, are given in table 1. Statistically, the parameter of the qualitative drought variable was found to be significantly less than zero for each crop. The corn equation excluding the drought variable exhibited a slight positive autocorrelation that disappeared when the drought variable was included. Although the proportion of yield variation explained by the model was small, the influence of the drought variable on corn yields was important; the expected value of corn yield in a drought period is 4% lower than in a nondrought period as depicted in figure 2. For soybeans, the expected value of yield during a drought period was about 2% less than for a nondrought period.

Wheat exhibited a slightly different pattern. For the ordinary least squares estimate, expected yields were 3.4% lower in a drought *vis-à-vis* nondrought period. There was, however, evidence of positive autocorrelation. The equation was reestimated using Hildreth-Lu methods; the maximum likelihood estimate of the autocorrelation parameter was 0.2. Correcting for serial correlation dropped the expected drought impact from 3.4 to 2.6%.

Similar results were obtained using U.S. average yield data (see table 2). The drought variable is, statistically, significantly less than zero for each crop. A slightly different statistical model than that used with the McQuigg, Thompson, and LeDuc data was employed since these data were not on a "constant technology" basis. Yield was regressed on trend and the same binary drought variable used in the analysis of the McQuigg data; intercept and trend shift parameters were used to account for the introduction of new technology and the greater use intensity of traditional inputs following the late 1930s. For corn and wheat, intercept and trend shift parameters were specified beginning in 1938; 1940 was the "shift year" used for soybeans. Alternative specifications of the "shift year" did not change the statistical significance of the drought variable.

The period 1866 to 1960 was used for corn. The series that converted all corn to corn for grain was terminated in 1960, while the newer series for all corn originated in 1919. The impact of the drought variable reduces the expected value of corn yield by 6.3% *vis-à-vis* 4% for the shorter McQuigg series. The events since 1960 remain consistent with the drought cycle hypothesis. Yields during the 1960s were average or above average while the period beginning in 1974 exhibited lower yields, on the

Table 2. Parameter Estimates for "Drought Cycle" Model for U.S. Average Yields

Crop	Period	Average Yield (bu./acre)	Drought Variable (bu./acre)	R^2
Corn	1866–1960	28.8	−1.81	.069
			(2.57)	
Soybeans	1924–1970	19.5	−1.31	.179
			(3.08)	
Wheat	1866–1970	16.0	−.65	.03
			(1.89)	

Note: The t values are given in parentheses. Critical t values are the same as given in table 1.

average, than would have been expected as a result of drought and early fall frost.

The decrease in the expected value of soybeans was 6.7%, a larger decrease than for the McQuigg data. The decrease for wheat was 4.1%, which was slightly larger than that obtained from the McQuigg series.

Two-year cycles were also tested by specifying a binary variable which equaled one in alternate years, zero otherwise, using both the McQuigg data and the national average yield data. Although not presented, the parameter estimates of the two-year cycle model were not statistically different from zero for both sets of data.

Conclusions

The empirical findings of this study are consistent with the existence of drought cycles for corn, soybean, and wheat yields. However, not every year within a drought period exhibits below average yield and vice versa. There was no evidence for a two-year cycle.

These findings are relevant for price analysis and have extremely important economic implications given the relatively inelastic nature of demand, particularly for wheat and corn. The implications for price stability analysis and agricultural policy administration, including grain reserves, are evident.

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Machinery Selection and Crop Planning On a State Farm in Iraq

Abdulla Danok, Bruce McCarl, and T. Kelley White

Iraq has established state farms to serve as demonstration units for the introduction of new technology, to produce improved seed, and to produce agricultural products. This study focuses on the Nai State Farm as a case study of an important set of problems facing state farms in Iraq. These problems involve machinery selection, machinery management, crop selection, labor management, and profitability. A diverse machinery complement on the Nai farm has led to difficulties with maintenance, spare parts, and tractor-implement compatibility. There also appears to be an excessive number of machines for the land area under cultivation.

Crop selection has not been coordinated effectively with machinery selection and labor availability. The crop mix frequently possesses uneven seasonal labor and machinery requirements. Thus, peak resource demand is much greater than average demand and creates problems of labor and machinery utilization. Failure of the Nai Farm to produce profit also has reduced its effectiveness as a demonstration farm.

Machinery selection, crop selection, and job scheduling are interrelated and require an integrated planning process that can evaluate simultaneously the effects of machinery purchase and crop production alternatives within the resource constraints imposed on the farm. Machinery selection is made more difficult by the limited number of discrete machine sizes available. The less-than-perfect substitutability of machinery services performed at different times further complicates machinery selection, scheduling, and crop planning.

The objective of the research reported in this paper was to develop a planning process for choosing a machinery complement consistent with a total cropping plan for a state farm in Iraq and to examine the economic consequences of better planning. An optimizing model was developed to solve simultaneously for machinery selection, crop production, and labor hiring. A further purpose of this paper is to illustrate an efficient solution procedure for this type of model. While the model structure developed is applicable to a wide range of sizes and types of farms, the application presented in this paper is specific to the Nai State Farm.

The Nai State Farm

The Nai farm is located in the central part of Iraq, about 90 kilometers north of Baghdad. The total area of this farm is 19,040 donum (one donum is 2500 square meters or .618 acres), with a net cultivatable land area of approximately 16,000 donum. Currently, the cultivated area is only 4,500 donum because of the limited irrigation infrastructure. The farm uses both permanent and temporary labor. Temporary labor is used primarily to perform unmechanized operations.

The Nai farm, as well as the other state farms, is supported by the government—it pays directly all wages, salaries, and for machinery purchased. Thus, the state farms, in general, have no real constraint on capital availability.

A detailed description of the Nai State Farm and sources of data used is presented by Danok. Data related to land area, crop performance, crop inputs, machinery, and labor were obtained from farm records. Secondary data were used to obtain working time distributions, crop timeliness factors, crop prices, and input prices. Performance data from the United States and other countries were used for machinery for which farm or local performance data could not be obtained.

The BAATH Model

The BAATH model assumes the farm is a profit-maximizing entity which accepts exogenously determined input and factor prices. The cropping possibilities are wheat, flax, clover, safflower (fall and spring), cotton, and corn (fall and spring). Vegetable production is not modeled; rather, the resource base is adjusted to reflect its presence. Production of each crop involves plowing, discing, planting, irrigation, and harvesting operations. These operations are performed at working rates which vary by crop over the agricultural working year. The year is disaggregated into twenty-four periods. Resources

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are available in each of these periods. Crops are planted and harvested in various periods with varying yields depending on agronomic characteristics.

The BAATH model, further, has variables which select a machinery complement from an available set of tractors (60, 70, 75, 80, 100 horsepower), plows (3, 4, and 5 furrow), discs (14 and 19 feet), grain drills, corn planters, grain combines (14 and 22 feet), and cotton harvesters. The purchase of fractional machines is not allowed and machinery rental is not considered.

A machinery complement is selected assuming there is no existing machinery. Variable operating costs, revenues, and amortized annual ownership costs enter the model. The crop production plan chosen is repeatable year after year and assumes certainty in terms of technical coefficients and prices.

The model is operationalized as a mixed integer programming formulation with 863 columns and 610 rows. The following questions overview the model structure. The objective function,

$$\text{(1)} \quad \text{maximize } RH - CY - UZ - BP - ED - FS - AI - OT - VX,$$

maximizes the revenue from harvesting crops (R) times the area harvested (H); minus the amortized costs of implements (C) times integer variables representing implement purchase (Y), minus the amortized costs of power sources (U) times integer variables (Z) representing power source purchase; minus the plowing costs during each time period using each relevant combination of power sources and implements (B) times the area plowed (P); minus the discing cost by period using each relevant power source and implement (E) times the area disced (D): minus the planting cost by crop, time period and equipment used (F) times the area planted (S); minus the irrigation cost by crop and time period (A) times the land area irrigated (I); minus the cost of permanent labor used for temporary labor jobs by period (O) times the amount used (T); minus the cost of hired labor by period (V) times the amount of labor hired (X).

This objective is maximized subject to a series of constraints illustrated by relationships (2–16). The feasibility of having certain sizes of implements relative to the availability of power sources is given by

$$\text{(2)} \qquad \delta Y - \gamma Z \leq 0,$$

where δ is a matrix of ones and zeros depending upon whether certain implements require specific power sources, and γ is a matrix of ones and zeros which specify whether a power source permits certain implements to be present.

The land area limitation on the farm is given by

$$\text{(3)} \qquad LP \leq TA,$$

where L is a vector of ones which sums up all plowing activities (P) and requires them to be less than or equal to total acreage (TA).

The intermediate products of plowed, disced, planted, and harvested land are given by

$$\text{(4)} \qquad -G_pP + G_FD \leq 0,$$

$$\text{(5)} \qquad -G_pD + G_FS \leq 0,$$

$$\text{(6)} \qquad -G_pS + G_FH \leq 0, \text{ and}$$

$$\text{(7)} \qquad -G_pH + G_FP \leq 0,$$

where Gp is a general matrix of ones and zeros reflecting periods in which land processed by a preceding activity output may be used, and G_F reflects the use of land processed by a preceding activity by a succeeding activity. Thus constraints (4) through (7) require that an acre to be disced must first be plowed, an acre to be planted must first be disced, an acre to be harvested must first be planted, and an acre to be plowed must first be harvested. These constraints exist by crop and time period.

Irrigation is represented by two constraints:

$$\text{(8)} \qquad R_IS - I \leq 0, \text{ and}$$

$$\text{(9)} \qquad WI \leq TW,$$

where (8) balances irrigation requirements (R_I) times acreage (S) and irrigation supplied (I), and (9) constrains irrigation water use (WI) to be less than or equal to water supply in each period (TW).

Machine operating time availabilities are represented by

$$\text{(10)} \qquad -JZ + K_pP + K_dD + K_sS + K_HH \leq 0,$$

$$\text{(11)} \qquad -M_pY + N_pP \leq 0,$$

$$\text{(12)} \qquad -M_DY + N_dD \leq 0,$$

$$\text{(13)} \qquad -M_sY + N_sS \leq 0, \text{ and}$$

$$\text{(14)} \qquad -M_HY + N_HH \leq 0,$$

where J is a matrix of working time made available by purchasing power sources (Z) and the requirements for this resource arising from plowing (K_pP), discing (K_dD), planting (K_sS), and harvesting (K_HH). Constraints (11) through (14) balance the implement working time obtained by purchases (M_tY) with the time used by plowing (N_pP), discing (N_dD), planting (N_sS), and harvesting (N_HH), respectively.

Finally, there are two constraints on labor:

$$\text{(15)} \qquad Q_pP + Q_dD + Q_sS + Q_HH + T \leq TL, \text{ and}$$

$$\text{(16)} \qquad Q_{tH}H + Q_tI - T - X \leq 0,$$

where (15) restricts labor use for plowing (Q_pP), discing (Q_dD), planting (Q_sS), and harvesting (Q_HH) to be less than or equal to total permanent labor supply (TL). Permanent labor may also be transformed to do temporary labor jobs via T. Equation (16) relates the use of temporary labor in harvesting ($Q_{tH}H$) and irrigation (Q_tI) to be less than or equal to transformed permanent labor (T) plus hired temporary labor (X).

Solution

The solution algorithm for the BAATH model is based on Benders Decomposition (Benders; Hilger, McCarl, Uhrig). The model decomposes into an integer programming problem with 99 variables and 25 rows, and a linear programming problem with 764 columns and 585 rows. The integer program selects machinery given costs and information (through Benders cuts) on the value of machinery resources. The linear program selects the best crop plan given a set of machinery. The iterative solution of the two submodels via the Benders procedure results in simultaneous optimization of machinery and crop plan. The algorithm was started with a solution obtained by rounding the linear programming solution. Model convergence was accelerated through the addition of three constraints. These constraints specified minimum numbers of tractors, plows, and discs. The minimums were set considerably below current operating levels and below the linear programming optimum. These constraints specified minimum numbers of tractors, plows, and discs. These constraints caused the model to avoid nonsensical solutions. These constraints also are useful to decrease the computer cost of solving the model. Their usefulness was demonstrated in a small sample problem where these constraints reduced iterations 66% and solution time 50%.

The algorithm was terminated after fifteen iterations. The model was solved until the bound spread reached 3.27% of the final best objective function value. Thus no solution could be obtained with an objective function more than 3.27% better (Benders; Hilger, McCarl, Uhrig). The computer cost of this run was $56 using 862 seconds of CDC 6500 computer time.

Application and Results

The model as presented above was used to find an optimal machinery complement and crop plan. However, to aid in interpretation of the solution several other configurations were studied using the linear farm planning module. These configurations involved the imposition of both the different machinery sets (optimal versus actual) and different land use restrictions (actual 1972–73 allocation of land to crops [fixed crops] versus an unrestricted crop plan [free crops]). In addition to the four combinations arising from the machinery and cropping alternatives, one additional run was made which was designed to duplicate as much as possible the 1972–73 farm situation. This plan had the actual machinery and actual crop acreage and cropping activities restricted to the specific planting-harvesting dates and acres which the farm had in 1972–73 (fixed date). Results of these runs are presented in table 1.

Table 1 contains the farm income, crop plan, and labor use for each of the five runs. These results may be used to identify the individual effects of machinery selection, job scheduling, and crop selection, as well as their interactions. This will be done by comparing model results when constrained to actual crop plan, job schedule, and machinery set with results when various constraints are relaxed. First, however, model verification will be discussed.

Model Verification

Given data limitations, the only test of model validity possible was to impose the actual machinery complement and crop plan, including date of performance of operation, on the model (fixed date – actual machinery) and compare model results with actual farm accounts. The actual crop plan was feasible and the crop schedule, yields, and revenue generated were consistent with actual farm results. The objective function value resulting from this model run was −14,844 Iraqui dinars (I.D.). In comparison, the actual farm lost 25,930 I.D. This difference is largely due to actual labor hiring which exceeded model labor hiring by approximately 38,000 hours (60% more). The lower level of labor hired in the model is explained by four factors: (*a*) hours hired were assumed to equal hours worked and made no allowance for vacation, sick leave, etc.; (*b*) no inefficiencies in actual labor utilization were allowed; (*c*) labor for overhead operation was not included in the model; and (*d*) permanent labor may substitute more freely for hired labor in the model than is actually possible. If adjusted for the cost of hiring the additional 38,000 man-hours of labor, the objective function value for the model would be −24,390 I.D. Based on this result, it was decided that model performance justified further experimentation.

Total Effect of Optimization

The total effect of simultaneously optimizing machinery complement, crop plan, and scheduling can be shown by comparing solutions for the free crop-optimal machinery and fixed date-actual machinery runs (table 1). Profit for the free crop-optimal machinery (FO) situation was 4,571 I.D., an increase of 19,595 I.D. over the fixed date-actual machinery situation. The increase in profit occurs, in part, from cost-saving due to a reduction in number of machines. The comparison shown in table 2 indicates only about one-half as many major items of machinery in the optimal set. Larger combines are selected and cotton harvesters are added to the optimal set.

A comparison of the crop plans shows a larger area planted to safflower, clover, cotton, and corn, and less to flax, while wheat does not enter the FO plan. The FO plan also includes more double cropping. By mechanizing the harvesting of cotton and achieving a more even distribution of labor re-

Table 1. Plan Comparisons under Alternative Machinery and Crop Assumptions

	Planted Crops		Transformed	Hired Labor		Farm[a]	
Plan	Crop	Area (Donum)	Permanent Labor (hr.)	Period Used P_t	Amount (Hrs.)	Income I.D.[b]	Profit[c] (I.D.)
Free crop-optimal machinery	safflower (a)[d]	3,333.23		5	1,977	26,683	4,751
	clover	635.88	44,563 (during all periods)		1,160		
	flax	287.73					
	safflower (s)[d]	243.06					
	cotton	635.88					
	corn (a)	287.73					
Fixed crop-optimal machinery	wheat	2,000		5	2,436	19,402	−2,530
	safflower (a)	900	23,751 (during all periods except period 7)	6	897		
	clover	500					
	flax	1,000					
	cotton	500					
	corn (a)	250					
Free crop-actual machinery	safflower (a)	2,568.66	39,051 (during all periods except 2 and 3)	2	43,889	17,402	−4,530
	clover	512.82		9	719		
	safflower (s)	1,418.52					
	cotton	512.82					
Fixed crop-actual machinery	wheat	2,000	31,419 (during all periods except 17)	2	43,010	10,794	−11,138
	safflower (a)	900		6	1,388		
	clover	500		7	18,454		
	flax	1,000					
	cotton	500					
	corn (a)	250					
Fixed date-actual machinery	wheat	2,000	29,836 (during all periods except 14)	1	43,072	7,088	−14,844
	safflower (a)	900		6	1,388		
	clover	500		7	13,380		
	flax	1,000					
	cotton	500	12	12	66		
	corn (a)	250					

[a] Farm income = gross income − machinery cost.
[b] At the time of this study the exchange rate was 1 I.D. = $3.37.
[c] Profit = farm income − permanent labor cost.
[d] (a) autumn (s) spring.

quirements among seasons, the free crop-optimal machinery plan used only 3,137 man-hours of hired labor in comparison with 62,907 man-hours for the fixed date-actual machinery plan. Reduced labor cost alone accounted for about 75% of the profit difference. Thus, it is clear that the major gain from crop plan and machinery optimization was in the form of cost reduction, labor, and machinery, rather than increases in revenue.

Effect of Machinery

The effect of machinery selection can be seen by comparing model results with optimal versus actual machinery for both the free and fixed crop situations. For the free crop situation, the optimal machinery set results in 9,281 I.D. more farm income and 41,470 hours less hired labor than did the actual machinery set. With the crop plan fixed, farm income was greater by 8,608 I.D. and labor hiring was reduced by 59,579 man-hours by use of the optimal machinery set. While the optimal machinery set was not chosen to be "best" for the fixed crop plan, it was superior to the actual machinery set. The inclusion of cotton harvesters in the optimal machinery set seems to explain its advantage over the actual set.

Effect of Crop Selection

Comparisons of model results for free versus fixed crop situations with optimal and with actual ma-

Table 2. Machinery Comparison between Actual and Optimal Sets

Actual Set		Optimal Set	
Machine or implement	# units	Machine or implement	# units
60 h.p. tractor	8	60 h.p. tractor	7
70 h.p. tractor	1	70 h.p. tractor	3
75 h.p. tractor	8		
Combine w/grain header 14′	6	Combine w/grain & corn header 22′	3
Grain drill	4	Grain drill	10
Cotton planter	2	Cotton planter	3
Corn planter	2	Corn planter	4
4-furrow plow	5		
3-furrow plow	6	3-furrow plow	6
Disc plow	1	Disc (14′)	2
Disc harrow	2	Cotton harvester	7

chinery provide a measure of the effect of optimization of crop selection. The farm income gain from crop optimization was 7,281 I.D. with optimal machinery and 6,608 I.D. with actual machinery. The difference in labor hired was 197 hours for optimal machinery and 18,244 hours for actual machinery reflecting the mechanization of corn and cotton harvesting under the optimal machinery system. The relatively equal advantage of optimal crop planning across two rather different machinery systems illustrates the importance of a comprehensive planning approach. However, it is important to note that the return to crop selection alone is only about one-third the return to jointly optimizing crop, machinery, and scheduling of operations.

Effect of Job Scheduling

Comparison of results from fixed crop-actual machinery and fixed date-actual machinery model runs (table 1) illustrates the effect of optimal job scheduling when both crop plan and machinery complement are fixed. Farm income was increased by 3,706 I.D. and labor hired was reduced by 540 man days. While the reduction in hired labor was significant, it explains only a small part (8%) of the increase in farm income. The more important effect is the increase in crop yields resulting from more timely operations.

Conclusions

The Nai State Farm has a history of continuous losses. This study indicates that a plan achieved by simultaneously optimizing machinery complement, crop combinations, and scheduling of operations would be profitable. The actual operation was shown to be utilizing inefficiently both labor and machinery. In the optimal plan, major reductions in hired, temporary labor were achieved by substitution of capital for labor through mechanization of cotton and corn harvesting. Better utilization of permanent labor was shown to be another way of reducing hired temporary labor.

Unlike many less developed countries, Iraq has a very low rate of unemployment, and wages are rising. This indicates that the social cost of underemployment, as encountered on the Nai State Farm, is increasing. It is also important to recognize that, in the long run, increasing real income levels will depend on increasing labor productivity. Thus, the substitution of capital for labor as suggested by this micro analysis considering only private cost and return may well be socially desirable for Iraq.

The attempt to disaggregate the total effect of optimization indicated gains from optimization of a machinery complement, crop plan, and operation scheduling individually. While there is some confounding of effects in the comparisons used (especially of operation scheduling into crop and machinery), it is clear that the total effect of simultaneous optimization is greater than the sum of the individual effects. Thus, an important advantage of the comprehensive planning model is the simultaneous consideration of the interactions between land, water, time and labor constraints, and crop and machinery selection.

More efficient utilization of the fixed labor force was a major source of increased farm income. Labor use efficiency was increased by mechanizing the harvesting operation for corn and cotton and by increased double cropping to even out labor requirements. This indicates the need for comprehensive planning to identify bottlenecks and choose the most economical means of alleviating them rather than simply mechanizing the entire operation.

A model of this type is expensive to construct but, once available, is relatively inexpensive to use in farm planning. Thus, a conclusion drawn from this study is that the use of a planning aid, such as the BAATH model, has considerable potential for improving the economic efficiency of state and other large farms.

This study used Benders Decomposition to solve a large mixed integer programming model. The cost of running the mixed integer was only seven times higher than running just the linear programming problem (including the machinery activities) and was small compared to potential gains. In terms of machinery selection, the technique is not yet at a stage that would be practical for routine extension use, but work is being done on an alternative formulation which chooses among relevant machinery complements and exploits the structure of decomposition.

Several limitations need to be mentioned. A part of the difference between the results of the optimal plan and the actual situation on the Nai State Farm may be due to an inconsistency between the objective function of the BAATH model and that of the agricultural administration in Iraq. It is clear that profit maximization is not the sole objective. Thus,

caution must be exercised in drawing implications about the desirability of changes in machinery and crop combinations. However, with the "optimal machinery complement," the simulated farm was shown to be considerably more profitable in producing the same combination of crops. A demonstration farm would seem to be more effective if operated profitably.

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How Farmers Viewed Farm and Food Policy Issues Compared with Selected Provisions of the 1977 Agricultural Act

Harold D. Guither and Bob F. Jones

During November and December 1976, opinion surveys of a sample of commercial farmers were taken in Illinois, Indiana, Minnesota, Alabama, Georgia, and Tennessee to determine farmers' views on current issues relating to farm legislation that Congress would consider during 1977. The only differences in the questionnaires were inclusion of questions about commodities grown in the South that would not apply in the Midwest.

Introduction

The purpose of this paper is to compare farmers' views with selected final provisions of the 1977 Food and Agricultural Act. These 1976 farmer opinion surveys represent a unique coordinated effort by agricultural economists in the six states to develop questions on policy issues that would be considered in upcoming legislation.

In each state the sample of farmers surveyed was drawn by the State Crop Reporting Service from the total file of farmers. Sample size and number of usable questionnaires were as follows: Illinois 1500, 460; Indiana 1500, 609; Minnesota 1350, 485; Georgia 1485, 512; Alabama 1497, 410; and Tennessee 4400, 631. The sample drawn in each state was intended to represent a cross section of commercial farmers. Table 1 provides some measures of socioeconomic characteristics.

Previous Policy Issue Surveys

Previous surveys have shown farmers' attitudes and values on farm policy issues. For example, Hines, Hatesohl, and Tweeten reported that in Oklahoma and Kansas in 1964, four out of five favored some government program to support farm income. They pointed out that although 30% favored government support of farm prices, farmers did not want government to tell them what to do.

In a 1970 survey of Illinois farmers, Guither concluded that farmers could use help in understanding economic relationships underlying policy issues. In 1971, Driss and Breimyer surveyed farm leaders in Missouri and showed the conflict on foreign trade issues.

In 1975, Hendren and Breimyer surveyed Missouri farm leaders and found that farmers felt they were underpaid, the 1973 farm law was OK but loan and target prices should be higher, and grain reserves were desirable but farmers should manage them.

Future Legislation Preferences

Because the 1973 Agriculture and Consumer Protection Act was due to expire at the end of 1977, farmers in the surveys were asked what they thought Congress should do about future farm legislation in 1977. In each of the six states, a majority ranging from 52% to 72%, as shown in table 2, favored revising the 1973 Act by raising target prices and loan rates closer to cost of production but keeping the law in about the same form. The alternative of eliminating all government price and income support programs was not an acceptable choice, responses ranging from 5% to 23%.

The decision by Congress to pass the 1977 Act and raise target prices and loan rates is in line with a majority of farmers' responses in all six states.

Setting Target Prices and Loan Rates

A major issue during 1977 legislative efforts was the level at which target prices and loan rates would be set. The Senate bill set levels higher than the House or the administration recommended. For 1977, farmers surveyed in the six states recommended an average wheat target price of $2.88 to $3.24, a wheat loan rate of $2.61 to $2.95, a corn target price of $2.16 to $2.34, and a corn loan of $1.95 to $2.16, as shown in table 3. The administration had recommended a $2.47 wheat target price, $2.25 wheat loan, $1.70 corn target price, and $1.50 corn loan. Even though the final figures in the Act were not as high as the farmers surveyed had wanted, they were closer than what the administration had first suggested.

Some regional differences were noted among farmers' responses. Midwestern farmers favored higher wheat target prices and loan rates than those in the South. Southern farmers averaged higher

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Table 1. Characteristics of Farmers Surveyed

Characteristic	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee
	%					
Age						
Under 30	5	2	7	7	3	3
30–39	14	11	14	10	11	11
40–49	19	23	22	17	16	20
50–59	31	30	32	25	33	27
60 & over	29	34	24	39	37	39
No answer	2	—	1	2	—	—
Education						
Grade school	20	17	31	19	21	27
Some high school	11	14	11	21	13	17
High school graduate	41	48	38	29	32	25
Some college	15	11	11	12	13	15
College graduate	11	10	8	15	20	16
No answer	2	—	1	4	1	—
Farm Organization Member						
Farm Bureau	75	56	25	64	72	73
Farmers Union	3	5	28	1	[b]	[b]
Grange	1	1	1	[a]	[b]	1
NFO	3	3	9	[b]	7	10
Major Income Source						
Grain—soybeans	64	55	33	33	23	[b]
Hogs, beef cattle	9	16	15	29	13	
Dairy	5	4	25	3	5	
½ grain, ½ livestock	17	18	20	—	18	
Other	5	7	7	35	41	
Average acres farmed	400	280	373	194	469	267
No. usable responses	460	609	458	410	512	631

[a] Less than 0.5%.
[b] Not reported.

target prices than corn loan rates than those in the Midwest. Southern farmers had more variation in soybean loan rates than those from the Midwest.

Method of Setting Target Prices

The 1973 Act established target prices, with provision for annual adjustment beginning in 1976 based on changes in the index of prices paid for production items, interest, and taxes.

Surveyed farmers were asked on what basis target prices should be established. Choices included the method used in the 1973 Act, the cost of production, the parity price principle, or other. In all states except Minnesota, farmers showed a preference for use of current target price with adjustments for prices farmers pay for production items, including labor and interest (table 4). However, from one-fifth to one-third of those responding preferred use of cost of production for the major producing area including average land cost. A smaller percentage favored use of the parity price principle.

The 1977 Act raised the level of target prices to establish a new base from which annual adjustments would be made after 1978, basing that adjustment on changes in variable costs, machinery ownership costs, and general farm overhead costs. Land costs are not included. (U.S. Congress, Public Law 95-113, sections 401, 501, and 602.) It appears that this method represents a compromise between that used under the 1973 Act and a shift to a complete cost-of-production basis. The 1977 Act is then partly in line with the responses of surveyed farmers.

Use of Set-Aside Programs

Farmers were also asked in the survey to give their views on whether or not a set aside should be used if needed, or if an on-farm storage program should be substituted instead.

Although no set-aside program had been in effect since 1973, one-third to one-half of those responding favored use of a set aside if needed (table 5). From 18% to 38% did not favor use of a set-aside program. Almost as many favored use of a program that would set aside production from a specified acreage in a long-term, on-farm storage program financed by government. Stronger support for a set aside is evident from the three southern states.

Table 2. Preferences for Future Legislation

What should Congress do in 1977?	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee
	%					
Revise the 1973 Act—raise target and loan prices, keep present form	53	59	67	52	72	61
Keep the present law—extend for a period of years	7	6	5	10	10	9
Let law expire—go back to earlier laws	3	3	1	4	2	4
Eliminate all price and income support programs	23	22	14	14	5	14
Other (no opinion, no answer)	14	10	13	20	11	12
Total responses	460	609	458	410	512	631

Sources: Christiansen; Guither; Johnson; Jones and Litzenberg; McManus and Humberd; Wilson, Adrian, White.

Table 3. 1977 Target Prices and Loan Rates Averages Recommended by Farmers in Six States & 1977 Act; November 1976 Farm Prices

Crop	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee	1977 Food & Agr. Act.	November 1976 Farm Prices
	$							
Wheat target	3.06	3.02	3.24	3.05	2.99	2.88	2.90	2.46
Wheat loan	2.75	2.74	2.95	2.61	2.84	2.69	2.25	—
Corn target	2.22	2.16	2.18	2.34	2.29	2.21	2.00	2.02
Corn loan	1.99	1.95	2.00	2.08	2.16	2.07	2.00	—
Soybean loan	4.11	4.01	4.06	4.01	4.38	3.79	3.50[a]	6.11
Cotton target	—	—	—	.62	.59	.55	.478	.652
Cotton loan	—	—	—	.51	.54	.50	.426	—

[a] At the discretion of the secretary of agriculture.

Table 4. Farmers' Preferences for Setting Target Prices

Method	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee
	%					
Current target, adjust by index of prices farmers pay	40	50	36	46	39	63
Cost of production	35	37	37	21	33	26
Parity principle of equal purchasing power	8	9	14	6	12	7
Other & no answer	17	4	13	27	16	4

Table 5. Farmers' Views on Set-Aside Programs

View	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee
	%					
Set aside should be available if needed	41	42	34	42	53	50
Set aside should not be used	29	38	25	20	18	27
Use farm storage program instead of set aside	17	16	32	23	18	21
Other & no answer	13	4	9	15	11	2

The 1977 Act gives the secretary of agriculture discretion to declare a set aside if the total supply of wheat, feed grains, cotton, or rice is likely to be excessive as determined by the Secretary's office. A majority of those responding to the surveys received at least part of what they wanted in the 1977 Agricultural Act.

Use of Government Grain Reserves and Price Stabilization

The need for a publicly held grain reserve has been discussed since supplies declined and prices rose in 1973 and 1974. Farmers were asked to express their views as to whether they believed government should hold some grain reserves, buying when prices are low and selling when they are high.

A clear regional difference of opinion among farmers was shown in the survey. A majority of Midwest farmers disagreed with the idea of government grain reserves, while a majority of those from the Southeast supported it (table 6). Part of this response may be explained by the fact that the southern farmers buy grain to supplement that which they produce for their livestock and poultry. They want more stable prices. The farmers in midwestern states, a grain surplus area, want high prices and are more apprehensive of government grain-handling operations.

The 1977 Act provided for a government grain reserve through an extended loan to producers to encourage on-farm storage. The law specifies a wheat reserve of 300 to 700 million bushels and an unspecified amount of feed grains. Loans would run for three to five years and would permit release of wheat when the market price reached 140% to 160% of the loan rate and release of feed grains at a level determined by the secretary of agriculture. Government-held stocks could be sold at 150% of loan if farmers held stocks under the three- to five-year loan program; otherwise, the government resale price would be 115% of the loan.

The statement in the survey was not an exact description of the reserve program authorized in the 1977 Act, which places more emphasis on farmer ownership of the grain reserve instead of government ownership.

Overall, the farmer responses dealing with government's role in stabilizing prices indicate some inconsistency. A majority responded favorably to a statement that farm market prices should be permitted to move up and down without government interference to guide farmers' production decisions. However, a majority in each state also agreed to a statement that the government should continue to use tax revenues to keep farmers' prices and incomes from dropping to low levels. And even though wide differences were noted in response to the suggestion that government should hold some grain reserves, the farmers in each state favored both higher target prices and loan rates than were in effect in 1976. Also, as noted earlier, a substantial percentage favored the idea of a government-financed on-farm storage program.

Food Assistance and Food Stamps

Responses would indicate that a majority of all farmers responding to the surveys support some type of food assistance program (table 7). However, there is some doubt among farmers that the program helps strengthen the demand for their products. The stated intent of Congress to limit participation in food stamp programs to those households whose incomes are keeping them from obtaining a more nutritious diet would also be supported by most farmers responding in the survey.

The 1977 Act made considerable revision of the food stamp program and set limits on federal expenditures for 1978 to 1981. The amount authorized exceeds the estimated costs of price support and commodity programs.

Analysis and Interpretation

A substantial majority of farmers in every state favor either adjustment based on the index of prices they paid for production items or a cost of production basis for setting target prices. The parity principle of equal purchasing power received from 6% to 14% preference in the six states, yet the strong call for 100% of parity from the American Agriculture Movement (AAM) in the winter of 1977–78 raises some questions. Had the opinion of farmers changed in one year? Or did the AAM represent a minority of about the magnitude shown in table 4? The contrast in views of the farmers in the survey and the AAM participants illustrates the difficulties in assessing farmer opinion in one period and as-

Table 6. Farmers' Views on Grain Reserves: To Stabilize Prices and Supplies, Government Should Hold Some Grain Reserves, Buying When Prices Are Low and Selling When They Are High

Farmer Opinion	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee
	%					
Agree	27	34	34	53	54	55
Disagree	61	56	50	27	32	35
No opinion (or no answer)	12	10	16	20	14	10

Table 7. Farmers' Views on Food Assistance

Questions Asked	Illinois	Indiana	Minnesota	Alabama	Georgia	Tennessee
	%					
Government should use tax funds to buy food for low income people:						
Agree	53	51	56	48	56	51
Disagree	31	37	27	30	28	34
No opinion (or no answer)	16	12	17	22	16	15
Food stamp and other food assistance programs help strengthen U.S. farmers' markets:						
Agree	42	37	50	44	60	45
Disagree	38	42	33	35	25	37
No opinion (or no answer)	20	21	17	21	15	18

suming these views will prevail at some later time.

Farmers' views on grain reserves need some further exploration. Although the views in table 6 clearly show Illinois, Indiana, and Minnesota farmers opposed to government holding of reserves with control of buying and selling; farmers in Alabama, Georgia, and Tennessee were more favorable to such government price-stabilizing actions.

However, farmers holding grain reserves as an alternative to set-aside programs received a varied response from 16% to 32% in the six states. If the farmer-held reserve question had been explored separately from set aside, a more favorable response may have been received.

Conclusions

A majority of farmers would like to make their production and marketing decisions without interference or influence from government. However, a majority would also like to see price and income support programs available in times of price declines and large supply.

Farmers share humanitarian concerns for people in need of food, both at home and abroad.

The survey revealed a surprising amount of agreement among farmers in the six different states on some issues, particularly the level of target prices, level of loan rates, and what should be done about revising the 1973 Act. The largest differences among states appeared in attitudes toward the role of government in stabilizing prices and incomes and in government ownership of a grain reserve.

The Food and Agriculture Act of 1977 appears to represent a reasonable compromise if we consider the views and preferences expressed by farmers responding to the six state surveys.

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Landspreading: An Alternative for Sludge Disposal

Stephen L. Ott and D. Lynn Forster

One characteristic of the 1970s is an increased awareness of the finiteness of our natural resources and their ability to assimilate the by-products of an industrial society. A result of this increased awareness has been the passage of the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500, 18 Oct. 1972) with the expressed goal that the national waterways will receive zero discharge of pollutants by 1985. One source of such pollutants has been the discharge of effluent from municipal wastewater treatment plants. As municipalities improve the environment quality of their effluent they are faced with another problem: how to dispose of sludge which is produced from providing cleaner effluent in an environmentally acceptable manner. In 1970, four million tons of sludge were produced, with a projected production of eight million tons by 1985 (Council for Agr. Sci. and Tech.).

Spreading sludge on cropland has received renewed emphasis not only as a low cost disposal method but also as a source of fertilizer nutrients. The objectives of this study are to (*a*) develop a model which optimally allocates treated sewage sludge to cropland and (*b*) apply the model to several communities in order to analyze the benefits and costs of using sewage sludge as a fertilizer resource under a variety of settings.

Characteristics of Sludge

Sewage sludge is a mixture of water and the inorganic and organic matter removed from wastewater by physical, biological, and/or chemical treatment. Sludge is a liquid with solids content of 1% to 7%. A reason for interest in landspreading is that it contains nutrients needed for plant growth. The amount of the major nutrients in dry sludge are as follows: total nitrogen 3.5%–6.5%, phosphate 1.8%–8.7%, and potash .24%–.84% (U.S. EPA). However, sludge may contain phytotoxic heavy metals (e.g., zinc, copper, nickel, cadmium, and lead) and disease-causing organisms.

Before sludge leaves the wastewater treatment plant, it is stabilized to reduce disease-causing organisms and odor. After stabilization, the sludge is spread on nearby land, incinerated, or dumped into waterways, oceans, lagoons, or sanitary landfills.

The discharging of sludge in waterways soon will be unacceptable, however. All methods of sludge disposal may be damaging to the environment. The landspreading of sludge at low rates minimizes the adverse environmental impacts, and it makes sludge a resource by supplying nutrients needed for plant growth.

Study Area

To determine the effects which the community setting has on the economics of landspreading sludge, four communities were selected from diverse physiographic regions in Ohio. The selected regions, representative of most of the eastern north central region, are the lake plain area of northwestern Ohio, the low lime glacial region of northeastern Ohio, the medium textured high lime, glacial till area of southwestern Ohio, and the nonglaciated area of southeastern Ohio. The chosen communities are Defiance (northwestern Ohio), Medina County (northeastern Ohio), Zanesville (southeastern Ohio), and Montgomery County (southwestern Ohio).

Typical of different regions of Ohio, these communities produce different amounts of sludge. Distance to acceptable landspreading areas also varies. The city of Defiance produces 970 dry tons of sludge a year with land acceptable for sludge-spreading adjacent to the wastewater treatment plant. The amount of Medina County-produced sludge usable for landspreading is 260 dry tons. Available land for sludge is located some two to five miles away from its wastewater treatment plant. Montgomery County produces the most sludge, about 1300 dry tons per year, and has the farthest distance to landspreading sites, about fifteen miles. Zanesville wastewater treatment plant is located some two miles from agricultural land, and it produces 600 dry tons yearly. For a more detailed description of the communities, see Ott and Forster.

Methodology

A linear programming methodology is used to determine which disposal technologies provide municipalities with the least-cost sludge disposal and to maximize the benefits which the community receives as a whole. Two models are developed to address the problem: the municipal cost minimization model (MCM model) and the community net economic benefit model (CNEB model). The MCM

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model analyzes only the cost of sludge disposal and determines a least-cost method of disposal. In this model, cropland is viewed as a place for sludge disposal only, i.e., crops grown do not generate any net revenue. It represents the objective of the community official interested in minimizing sludge treatment costs. The CNEB model identifies the system of sludge disposal that maximizes benefits to the community as a whole. With this model, the fertilizer value of sludge is taken into consideration and the net revenue from crops is recognized.

The sludge that leaves the wastewater treatment plant is disposed by landspreading, landfilling, or incineration. The models incorporate considerable detail in representing landspreading technologies for each of the four cities. The alternative landspreading technologies are a tank wagon pulled by tractor, a tank truck, a truck spreader, and a semitrailer "nurse" truck. Also, storage is available to permit seasonal storage of sludge when field conditions do not permit spreading.

Sludge may be spread on corn, soybeans, oats, wheat, alfalfa, and grass hay. Furthermore, these crops are grown on several soil types near a community. In addition, the models have a spatial orientation by representing these crop-soil type activities in several concentric circles surrounding a city. These concentric circles represent different distances from the wastewater treatment plant, and the cost of transportation increases as the sludge is spread farther from the plant.

An important parameter in the models is time. Each landspreading technology requires different amounts of time per dry ton to load, transport, and dispose of sludge. The farther the transport distance, the greater is the time required for sludge disposal. Each crop provides different amounts of time that are available for landspreading. There is a trade-off between those crops that generate high net revenue but limit spreading time and those that provide more spreading time but less net revenue.

The plant nutrients in sludge are unbalanced for most crops. Usually, the phosphorus needs of a plant are met before the nitrogen needs, and the amount of potassium supplied by sludge is low relative to plant needs. The models allow sludge to be spread at one of the three spreading rates. The first rate meets the phosphorus needs of the crop. At this rate, supplementary sources of both nitrogen and potassium are required. The second rate meets the nitrogen needs of the crop. When sludge is applied at this rate, excess phosphorus is added to most crops and supplementary potassium is needed. The third rate is applying no sludge to the land. Nutrients are supplied by commercial fertilizers and sludge is incinerated or landfilled.

An assumption of the model is that the marginal value product of nutrients in excess of crop requirements is zero. Thus, when spreading sludge at the rate to meet nitrogen requirements, the excess phosphorus has an opportunity cost as it could be spread on other crop ground where it has a positive marginal physical product. Therefore, when sludge is spread at the nitrogen rate the community may not be maximizing its return from the phosphorus in the sludge. On the other hand, when spreading sludge at the higher nitrogen rate, fewer acres are required. When spreading on these fewer acres, smaller travel distances are required, and transportation costs are less. For the community, the trade-off is between the opportunity cost of the excess phosphorus and the cost of the extra transportation.

The heavy metals found in sludge limit its use as a fertilizer. Agronomists have determined the maximum amount of heavy metals that may be applied cumulatively to the soil to prevent toxicity to the food chain (Thomas et al.). A constraint is placed on the model to assure that no cropland receives this heavy metal limit in less than twenty years.

Results

The results of the MCM model are summarized in table 1. For both Defiance and Zanesville, the lowest cost disposal method is landspreading by tank truck. Dewatering the sludge first and then landspreading it by truck spreader is the lowest cost disposal method for Montgomery County. In Medina County, landfilling is the lowest cost alternative. Medina County has higher landspreading costs because the necessary equipment to spread its relatively small amount of sludge has a relatively high cost per ton. If the tons to be disposed of were increased to 350 dry tons, then landspreading by tank truck would become the lowest cost disposal method. For Defiance, Medina County (if greater than 350 tons), and Zanesville, the next lowest cost disposal method is by truck spreader after dewatering. The truck spreader cost includes the cost of

Table 1. Annual Cost Per Ton for Sludge Disposal in the Four Modelled Municipalities

	Municipalities Modelled			
Technology	Defiance	Medina Co.	Montgomery Co.	Zanesville
Tank wagon	34.41[b]	72.06	273.96[b]	53.39[b]
Tank truck	20.27	61.58	121.09[b]	30.18
Truck spreader[a]	28.51	63.43	29.55	36.44
Hauling unit-tank truck	40.75	119.59	71.07[b]	58.65
Landfill	50.00	50.00	50.00	50.00

Note: Annual costs are for disposal of sludge. No nutrient returns are assigned.
[a] Includes dewatering costs.
[b] Requires more than one unit.

dewatering at $15 per dry ton. For these four communities, the tank truck and truck spreaders are the lowest cost landspreading alternatives, while the tank wagon and the hauling "nurse" unit are more expensive.

The choice of spreading technology is largely dependent upon the amount of sludge to be hauled and the distance it must be hauled. In cities with relatively large amounts of sludge and distant landspreading sites (e.g., Montgomery Co.), dewatering the sludge and truck-spreading is least cost. In cities with relatively small amounts of sludge and nearby landspreading sites (e.g., Defiance), spreading liquid sludge by tank truck is least cost.

The CNEB model analyzes sludge disposal systems from a community perspective, where crop returns as well as disposals costs are included. From the costs of disposal, net revenue produced by the crops is subtracted, and the system that results in the greatest net benefit is selected. For each community, the crops grown are restricted in order to be representative of local conditions.

In all four communities, landspreading at the phosphorus rate (meeting the phosphorus needs of the plants) gives the greatest net economic benefit (see table 2). The advantage of landspreading at the phosphorus rate over landfilling ranges from $37.12 per dry ton to $52.78 per dry ton, and over the nitrogen spreading rate (meeting the nitrogen needs of the plants) from $5.52 per dry ton to $14.07 per dry ton. In this study there was enough land in the disposal areas so that the sludge could be spread at the phosphorus rate without incurring extraordinary transportation costs. To test the sensitivity of these results to transport distance, the minimum landspreading distance is increased for each community. If all the sludge is forced to be spread in the next farther out disposal area, the phosphorus rate still gives the communities greater net economic benefit. Therefore, the marginal value product of the wasted phosphorus is greater than the marginal cost of transporting it over the range of transport distances.

These results show that sludge, instead of being a waste to be disposed of at minimum cost, is a resource which can be utilized in crop production. The spreading of sludge at the phosphorus rate rather than at the normal disposal spreading rate (nitrogen or higher) maximizes the use of sludge as a resource. Another advantage of spreading sludge at the phosphorus rate is that it lengthens the time sludge can be applied before heavy metals become a limiting factor in crop production.

The application of sludge does not change the crop mix of a region. In some regions the crop mix precludes summer spreading and requires the storing of sludge. The cost of storage is less than any subsidy the municipality might pay to farmers to grow lower value crops that allow summer spreading.

The landspreading of sludge is very insensitive to changes in the cost of fuel or labor. Labor costs can increase to $34.59 per hour and fuel costs to $7.55 per gallon diesel fuel, and landspreading is still optimal over landfilling. With this degree of insensitivity, it is unlikely that changes in labor or fuel costs will cause landspreading to become suboptimal.

Table 2. The Net Economic Advantages of Spreading Sludge at the Phosphorus Rate

	Communities			
	Defiance	Medina Co.	Montgomery Co.	Zanesville
Advantage over:				
Landfilling				
($/year)	51,195	11,804	48,259	28,328
($/ton)	52.78	45.40	37.12	47.21
Nitrogen rate				
($/year)	5,353	3,659	7,302	5,875
($/ton)	5.52	14.07	5.62	9.79

Summary and Implications

As a method of sludge disposal, landspreading on crops is highly desirable both from an environmental standpoint and from an economic standpoint. Landspreading transforms pollutants of waterways (nitrogen and phosphorus) into a resource (plant nutrients). With proper handling, environmental problems caused by the heavy metals and disease-causing organisms can be minimized. In terms of cost effectiveness, landspreading is less expensive than landfilling or incineration. The motor vehicle technologies of landspreading that are the least-cost methods of disposal are the tank truck for liquid sludge and the truck spreader for dewatered sludge. For smaller municipalities (1,000 dry tons or less) with short travel distance to the spreading sites (five miles or less), the tank truck is more economical. For larger municipalities and/or longer travel distances the dewatering of the sludge for disposal by truck spreader is more economical than disposal by tank truck. The spreading rate that maximizes the net economic benefit to the community from sludge is at a rate to meet the phosphorus needs of the crop. The landspreading of sludge does not affect the crop mix of a region.

Model results indicate that the institutional structure surrounding the disposal of sludge is an important determinant in the "best" landspreading system. In many communities, officials offer sludge as a free good to farmers, administratively allocating it. With sludge being treated as a free good, the municipalities try to minimize their disposal costs. The tendency is to apply sludge at a heavy application rate in order to reduce transportation cost and minimize the number of farmers with which the municipalities have to deal.

Treating sludge as a free good does not allocate sludge in a manner consistent with maximizing beefits to the community. If a market is established for sludge, its price and ultimate allocation is determined by the plant nutrients in the sludge. As farmers compete for sludge, they would bid up its price until the price is equal to the fertilizer value at the phosphorus spreading rate (a relatively low rate) less some risk premium. The risk premium is from the fact that sludge contains heavy metals, viruses, pathogens, or parasites and the nuisance factor of having landspreading interrupt farming operations. The municipalities will then spread the sludge at the phosphorus rate as they maximize their return from sludge as a resource. The community would realize substantially higher benefits with this market solution than with administrative allocation.

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The Welfare Effects of Erosion Controls, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt: Comment

Clayton Ogg

The recent *Journal* work by C. Robert Taylor and Klaus Frohberg (TF) was an impressive study from the standpoint of both the energy and imagination that must have gone into the model and the practical implications concerning the welfare effects of nonpoint pollution abatement. Yet, it appears that costs of nutrient management were considerably overestimated in the light of a number of experiments using techniques for controlling nutrient losses through proper timing of nitrogen fertilizer applications. Therefore, the model may have failed to represent the most cost effective techniques for reducing nitrogen pollution.

This failure to minimize costs appears to be the implication of Cornell publications by Bouldin, Reid, and Lathwell; and Lathwell, Bouldin, and Reid, who also cite supporting data representing areas in the Midwest and much of the rest of the country as well. By comparing the optimal fertilizer applications from the TF optimum application rates for high yielding corn with the optimum implied by Bouldin's fertilizer response curve, the apparent low level of management available in the linear programming model can be demonstrated. In the TF model (p. 29), 156 pounds of nitrogen were required to obtain an optimum yield for a specific price ratio and level of soil productivity. Given the same level of soil productivity and price ratio, Bouldin's optimum fertilizer application for summer sidedress fertilizer was less than half of TF's 156 pounds, and yields were comparable. Although TF do not specify the timing or the method of fertilizer management that their model permits for reducing pollution, Lathwell, Bouldin, and Reid cite fourteen Nebraska experiments (as described by Olson, Dreier, Thompson, Frank, and Grabouski) which suggest that applications in the 160-pound range are required to obtain optimum yield under a fall plow-down application technology. Again, summer sidedress produces the same yield from 80 pounds of nitrogen. During the years when fertilizer was relatively inexpensive, many farmers and the fertilizer industry still took advantage of the convenience of applying fertilizer in the fall or spring, partly to avoid risk that wet weather would interfere with sidedress applications. However, Bouldin, Reid, and Lathwell argue that rainy weather is precisely when economic effects of nitrate losses will be the most damaging.

Sidedressed nitrogen is used more effectively by plants than fall or spring plow-down because less is leached by rains. This is largely documented through measurement of the quite substantial differences in nitrogen content of above-ground dry matter (Bouldin, Reid, Lathwell).

Since TF simply designate nitrogen reduction as their model's "best management" technology for obtaining optimum yields under pollution control restraints, one can only infer why the estimates of loss in consumer surplus are so large. Failure to allow use of best technologies available can, of course, have a large impact on the model's policy implications.

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The Welfare Effects of Erosion Controls, Banning Pesticides, and Limiting Fertilizer Application in the Corn Belt: Reply

C. Robert Taylor and Klaus K. Frohberg

Ogg has raised an important issue regarding nutrient management and modeling technical alternatives for reducing nitrogen losses. However, we think that the experimental data he cites is atypical for actual farm conditions in the Corn Belt, thus leading him to conclude that the model bias is much larger than in fact it may be. Ogg's fertilizer response comparison is likely misleading for two reasons. One reason is that he refers to experimental response data, while the class of response functions we used was intended to apply to actual farm conditions. In an effort to determine how well experimental results applied to actual farm experiences, Taylor and Swanson made the following comparisons for Illinois: (*a*) experimental response functions versus functions that were based on judgments of agronomists familiar with farm practices; and (*b*) reported average corn yields versus average yields computed from an actual frequency distribution of fertilization rates and experimental response functions. Both comparisons indicated that the experimental response functions were much higher and typically had a different slope than the response functions farmers actually experienced.

Some likely reasons for the difference between experimental response functions and response functions actually experienced by farmers are: (*a*) the experimental plots are typically on the most productive soils, which may account for a very small part of the total cropland in the region; and (*b*) inputs, including tillage practices, weed and insect control, and fertilizer application, are more carefully controlled and used at optimal times, whereas labor considerations make such timing and control impractical in most farm situations. Hence, using a response function based on experimental data to represent actual farm conditions can be misleading.

A second reason that Ogg's comparison may be misleading is that he compared data for fall application with data for summer sidedress; our model assumed spring applications, a fact that regrettably was not given in the article. Fall applications of nitrogen fertilizer are not common in the central Corn Belt. Aldrich reports that less than 10% of the nitrogen fertilizer used in Illinois is applied in the fall, and part of this is applied to wheat; thus our assumption of spring-applied nitrogen seems reasonable. An analysis by Swanson, Taylor, and Welch of Illinois experimental data showed no significant optimal fertilization rate or yield differences between summer sidedress and spring applied nitrogen. However, significant differences were found for fall applications as compared to spring or sidedress applications. Although this study is not applicable to all Corn Belt soils nor the various climatic conditions in the area, it does suggest that the model bias resulting from not including sidedressing fertilizer as an alternative on nonsandy soils is not large.

Another factor that should be kept in mind when applying experimental data to actual farm situations is that the chemical formulation of fertilizer used in most experiments is more susceptible to leaching than the fertilizer used by farmers (Aldrich, p. 27). Thus, experimental data may overestimate the benefits of sidedressing nitrogen fertilizer.

There are many nonfertilizer cost differences that were not mentioned by Ogg, but which should be considered when comparing the economic efficiency of spring and summer sidedress applications of fertilizer. Some of these factors, outlined by Aldrich, are: (*a*) an extended period of wet weather at sidedress time may make application impossible until the corn grows beyond the state at which conventional sidedress equipment can move through the field (this would occur often in the central Corn Belt); (*b*) preplant application improves the distribution of labor; (*c*) sidedressing corn grown in narrow rows and on the contour is difficult and may cause plant injury; and (*d*) restrictions that reduce the length of the period during which nitrogen can be applied would increase the cost of nitrogen. These factors make sidedressing less attractive than comparisons based only on fertilizer cost and yield calculations.

Although we disagree with Ogg about the magnitude of the model bias, we do agree that the model and, thus, model results would be improved by including all technical alternatives for reducing nitrogen loss. Moreover, the ideal model would allow for differences in fertilizer response between re-

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gions and between soils within a region. However, a model that would include these factors along with demand considerations would be large indeed, and perhaps prohibitively expensive to solve. Thus we face a dilemma of slightly biased results versus significantly higher computational costs for less biased results.

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Books Reviewed

Anderson, Lee G. *The Economics of Fisheries Management.* Baltimore, Md. Johns Hopkins University Press, 1977, xviii + 214 pp., $14.00.

Economic research on ocean commercial fisheries has expanded steadily through the last two decades. Concurrently, economic data and analyses have become increasingly important for fishery management. However, material to educate people with limited economic training has been scarce.

Although it is now dated, Christy and Scott's volume remains an important introduction to the economics of international fisheries. Smith's book is a sound source for lay audiences interested in managing their own fishing enterprises. Also available are a number of studies of particular fisheries and analyses of particular issues. What has been missing in the literature is a basic text on the economics of fisheries management; Anderson has attempted to fill that gap.

The first two chapters introduce a basic graphical paradigm. First, demand, supply, indifference, cost, and production possibility curves are introduced and briefly explained. Then the basic economic model of a commercial fishery is set out. Constant prices for output and input, fixed factor proportions, and rather simple relationships between catch and biomass are used with the assumption of perfect competition. While these chapters are well-written and probably will be used heavily, particular instructors will wish to add readings not in Anderson's references. Since much of the theory in this book and elsewhere is normative, more welfare economics would be useful. Specifically, students should be alerted to the assumptions needed to formulate community indifference curves. Other useful supplements would be general introductions to imperfect competition and decision making under uncertainty.

In chapters three and four, additional complexities are added to the model. The latter chapter is more successful, particularly when the author is explaining his own contributions. Anderson is adept at developing analyses of multispecies fisheries, interdependence among species such as predator-prey relationships and international exploitation of fisheries using simple economic and biological models. A commendable feature of this theoretical volume is the tendency to close sections with qualifying comments on the departure of reality from theory in the issue treated.

Even though several complexities are introduced, the scope always stays on commercial fisheries. There is no attempt to deal with recreational fisheries, marketing of fish, community impact of fisheries, labor markets, or capital markets. While Anderson does introduce a variable price of fish into the model, he does not get into price analysis and never really departs from perfect competition as an assumption.

Chapter four deals with regulation and chapter five with "practical applications." While both are well written and useful, they are brief. Most instructors will want to use this volume as an introduction to the theory behind the management of commercial fisheries and use other sources for the applied aspects of their courses.

In summary, *The Economics of Fisheries Management* is really the "intermediate microeconomic theory of commercial fisheries management." Nonetheless, it is a unique achievement and will be a welcome addition to the currently available set of teaching materials in an expanding area of the economics profession.

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Smith, Frederick John. *The Fisherman's Business Guide.* Camden, Maine: International Marine Publishing Co., 1975.

Buchanan, James S. *Freedom in Constitutional Contract: Perspectives of a Political Economist.* College Station: Texas A&M University Press, 1977, xii + 311 pp., $13.50.

James Buchanan and Milton Friedman have both on occasion referred to themselves as "nineteenth century liberals." Others have referred to them as "conservatives." Both have written books with the word "freedom" in the title. There are some who speak of a "Chicago—V.P.I. axis" in which, presumably, Friedman and Buchanan would bemajor figures. However, I am convinced that the philosophical congruence between Buchanan and Friedman is quite incomplete and that Buchanan alone has a sound claim to the conservative label. Both men are enamored with the efficient solutions of neoclassical competitive models and both subscribe to a curiously atrophied concept of freedom, which they view largely as the absence of collective restraints on transactions among individuals. (On the other hand, I see freedom as a relative concept where, even in a textbook "free market" economy,

the freedom of any individual is defined precisely by the bounds on his opportunity broadly defined. To me, it does not follow that, because the market is free, the individual with the most tightly constrained opportunity set is free, or as free as anyone else.) Buchanan, however, tempers his concept of freedom with his concept of justice. And from this point, their philosophies further diverge: Friedman tends to recommend that, willy-nilly, inefficient arrangements be replaced with efficient arrangements and let the chips fall where they may; Buchanan insists that the "rules of the game" (his favorite metaphor) be changed only with the unanimous consent of the players. That is, the beneficiaries of existing inefficiency must be fully compensated for the loss of the arrangements that permit that inefficiency.

Buchanan subscribes to a conservatism that is deeper than his concern for Pareto-safety would alone suggest. He places immense normative stock in order and continuity. (In this respect, he occasionally sounds more like John R. Commons than Milton Friedman.) He seeks to reestablish a free and efficient society through the development of a sound constitution. Constitutions, it will be recognized, are devices by which the present both constrains itself and dictates to the future and, as time passes, the past dictates to the present. To Buchanan, truly desirable social arrangements must be established at the constitutional level, since weakly constrained democracy by majority vote will, due to selfishness, myopia, and a variety of game-theoretic "dilemmas," lead to all of the things Buchanan sees wrong with modern American society.

At the constitutional stage, Buchanan is comfortable with the underlying logic of the Rawlsian analysis. Individuals who "know everything in general and nothing in particular" (i.e., in particular they do not know their position in the society relative to the positions of others), should be able to agree on efficient and just arrangements for making social decisions. Justice is defined in process rather than outcome terms. Justice is whatever results from just processes; it is not some predefined utopian outcome. At the post-constitutional stage, day-to-day reallocation of resources and redefinition of rights and responsibilities would take place through contract among all concerned. At the post-constitutional stage, Pareto-safety is the working rule.

Buchanan's analysis of constitutional and post-constitutional "rules for making rules" is lucid and logical. His concept of a just social order is quite appealing. Whereas I would be offended by any suggestion of the sudden imposition of Pareto-safety on current society, I have no conceptual problem with Buchanan's two-stage, constitutional and post-constitutional blueprint for a just society. The pragmatic problem, well recognized by Buchanan, occurs at the constitutional stage. How can we expect to persuade a society composed of individuals who know more in particular than they do in general to withdraw behind the Rawlsian veil of ignorance to construct a just constitution, much less implement it?

This collection of essays, many of which have previously appeared elsewhere, is intended as a persuasive document (although it contains some excellent analytical passages) accessible to the intelligent noneconomist. Highly technical economic analyses are successfully avoided, but the reader conversant with economics and philosophy will have a distinct advantage.

As a persuasive document, it presents a mixed bag. Buchanan's well-reasoned and thoroughly reasonable critiques of writings by John Rawls, Robert Nozick, Richard Posner, and Michael Polanyi are perhaps the high points. He interprets Rawls sympathetically and with wisdom. His, perhaps reluctant, criticism of Nozick is sound. His devastating critique of Chicago's Posner is, if anything, a little understated. That particular essay, better than any other, highlights the fundamental distinction between Buchanan's true conservativism and the kind of claptrap put out on occasion by a few of the individuals in the Chicago School. However, there are also low points, in which Buchanan's anger at the Supreme Court, academic liberals, and student radicals overpowers both his analytical abilities and his better judgment, and thus undermines his attempt to preach to any but the already converted. His intemperate, ranting attack, now ten years old, on the academic response to student radicalism is analytically based on a false analogy (the university as a collective) and relies polemically on the inversion of "The Student as Nigger," a pernicious little pamphlet which made the rounds of campuses in the late 1960s. This essay would have been better left moldering in the trash can of history than republished in a book which includes much of genuine merit.

Buchanan is one of the most original modern thinkers and contributors in public finance and public choice. He is also a man of strong convictions, driven by a genuine anger at the directions being taken by modern society and an acute sense of being a member of an embattled philosophical minority. While dispassionate analysis is the most prized virtue in modern scholarship, it seems to me that some of the best and most innovative work comes from those propelled by strong passions. This does not disturb me as much as it does some others. I am comforted by Boulding's observation that the best protection from the intrusion of values in scholarship is "the criticism within the scientific community and the acute perception that we all have of the impact of the norms of others on their own thought, however blind we may be to the impact of our own norms on our own thought" (p. 810).

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Boulding, Kenneth. "Prices and Other Institutions." *J. Econ. Issues* 11(1977):809–21.

Gibbons, Boyd. *Wye Island: Outsiders, Insiders, and Resistence to Change*. Baltimore, Md.: Johns Hopkins University Press, 1977, xiii + 227 pp., $10.95.

Wye Island is among the larger of the many low, sandy islands that dot the eastern shore of the Chesapeake Bay. It was first cultivated by Europeans in the mid-seventeenth century and has been essentially agricultural since—tobacco, corn, cattle, and barley. It and its environs are peopled by two types: poor farmers and watermen who make their livings from the area's unusual combination of land and water resources and the very wealthy—corporate executives, cabinet members, and agency officials—who use the area as a retreat from the tensions and discomforts of their jobs in Washington, D.C., or Baltimore.

Because of its low population and general location, Wye Island is ripe for development, either for commuters or for second homes. The possibility of development brought stress to Wye Island and the stress, in turn, led Boyd Gibbons to write one of the most captivating and illuminating technical books I have ever read. Boyd Gibbons, a lawyer and staff writer for the National Geographic Society, became an amateur ethnographer and practiced this trade on Wye and the neighboring islands in the summer of 1974.[1] His story is a beautifully crafted chronicle of the events that preceded and accompanied an effort to develop the island into either a "planned community" or an area for the exclusive estates that would be permitted under large lot zoning.

The book cannot be put down. It spends a handful of pages describing the island itself then goes immediately to Jim Rouse, a developer who wants to buy the entire island, develop a number of small, high-density communities and keep the remaining land as open space for farming and recreational purposes. One cannot help but be on Rouse's side. Rouse is well-meaning and successful. He does everything right. He plans carefully. He hides nothing. His plan will not be disruptive; it will allow as many as 2,750 more people to live on the 2,800-acre island. He presents his plan, complete with environmental impact statements, plastic mockups, and maps, at a May 1974 meeting of the county planning commission.

Gibbons is a shrewd author. He tells us that this meeting was somewhat casual, but it is made clear that the locals are opposed to development. They are not enthusiastic about the Rouse plan, but Gibbons saves the showdown for later.

[1] At the time, Gibbons was a senior research associate with Resources for the Future. RFF sponsored his study and the book that came from it.

The scene shifts to the locals. They are described and quoted. Their lifestyles unfold in magnificent detail and, rich or poor, they are good, honest, sincere people. There is no malice. They display some melancholy and romance for a bygone era, but they also evoke a rather mature recognition that the present, and especially the future, must be vastly different from the past. And the past is detailed. A signer of the Declaration of Independence has farmed the island. As late as the 1930s a mildly sinister couple built a castle on the island and prevented access to it and to much of the island, as well. The watermen search for oysters and rely on uncanny senses in locating and exploiting the beds. They revel in a seedy tavern after a successful day of oystering. The rich don't live on the island but they can see it and want that vista maintained. Gibbons makes the island and its people come alive—still with little reference to the pending conflict.

The conflict between the islanders and the outsiders begins in the auditorium of a nearby intermediate school, but only after all contestants save two are proven to be honest, well-intentioned, and open-minded people. (The Hardy brothers are developers and speculators who will do nearly anything to recoup their heavy investments in Wye Island farms.) The conflict comes with all the fury of a midwestern summer storm. The tranquility of Wye Island becomes a counterpoint for the frenzy of tension, misunderstanding, and blame that accompanies the debate. It isn't the Rouse plan, its the "chickenneckers"—a derisive term used to describe all the nonresidents who frequent the island on summer weekends. The locals don't want change and their resistence is made clear in page after page, each pointing out one more thing that can happen if development is allowed to occur. In the end, the insiders carry the day. Rouse loses the $800,000–$900,000 he spent to prepare the plans for development. The Hardy brothers, while not losing, make only modest gain when the majority of the island is purchased by the State of Maryland in the fall of 1976. The state will lease the island out for farming and allow some hunting of waterfowl. There will be no buildings, no campgrounds, no boat landings, and no chickenneckers. Wye Island will remain much like it is.

This book is not about economics; it is a book about processes, planning, development, and people. The emphasis is on people. Unlike the scores of volumes that deal with planning for environmental purposes, or open space, or orderly growth, this one is about people. Those insiders who want to save Wye Island are not guided by a land ethic, they are guided by a people ethic. Boyd Gibbons spins a story of this ethic and the important events that surround it. His characters and his intrigues unfold for 224 pages, the last 89 filled with the tension attending the resolution of the problem. Only in the last four paragraphs of an "afterword" does Gibbons make his major point: The resistance

to change comes from a fear of new people rather than from any real concern with the environment or the carrying capacity of the land.

Who will read this book? It does not qualify as a text in economics, environmental engineering, or land use planning because it does not have a sufficient amount of disciplinary content. It should, however, be read by every practicing economist who is called upon to deal with land and people and it should be recommended to every land-use planner and every member of every planning group in the nation. The book is a considerable achievement; Boyd Gibbons should be rewarded through the courtesy of wide readership.

An afterthought. Gibbons' work is much like the work that any number of scientists are presently conducting in any number of locales. They are asking about the potentials for growth and the effects of growth. Their work will be reported in journal articles and experiment station bulletins filled with graphs, histograms, rank correlations, and tables. None, no matter how well done, can possibly have the meaning or the impact of *Wye Island*. The difference is people. Boyd Gibbons was not constrained by the impersonality of scientific language and because of this he has produced a book that will have meaning to all "insiders" and all "outsiders" wherever conflict arises between them.

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Maddala, G. S. *Econometrics*. New York: McGraw-Hill Book Co., 1977, xii + 516 pp., $19.50.

G. S. Maddala set out to write a comprehensive textbook intended for persons doing empirical econometrics. The author, a distinguished econometrician with substantial empirical experience, is obviously well-qualified to write this type of book. The product is good, but somewhat disappointing in that with additional effort it could have been superb.

Econometrics contains three major sections: first, an introduction to probability and statistical inference; second, an introduction to econometric methods; and third, further discussion of selected topics. Exercises and the usual tables are provided. Appendixes are used to present a few topics in matrix notation. Maddala usually succeeds in presenting the econometric topics at a level that persons can comprehend with a knowledge of ordinary algebra. In some instances, however, the author lapses into assuming too much of the intended audience. For example, the likelihood function is not adequately described for the student with limited training in statistics, particularly considering the use of maximum-likelihood concepts throughout the book. The author is ambivalent about the statistical sophistication of his intended readers.

Maddala's book is comprehensive. Historically, econometric models have been characterized as being simultaneous, dynamic, and stochastic, and simultaneous equation and distributed lag topics received great weight in the literature. Today, errors in variables, omitted variables, and other specification questions are getting increased attention. This book covers simultaneous equation and distributed lag models as well as the newer literature. Errors in variables receive almost as much attention as simultaneous equation models. There are excellent discussions of many "practical" problems, such as selection of variables, deflating, data transformations, proxy variables, mixing observations, grouping data, and seasonal and trend analysis. Separate chapters are devoted to pooling time-series and cross-section data, varying parameter models, and Bayesian methods.

The organization is somewhat unorthodox. For instance, the discussion of simultaneous equations models is contained mostly in the second section, while the discussion of autocorrelated residuals is contained mainly in the third section. Also, some topics are covered in several locations, but this is not always obvious from the table of contents or index. The variance of prediction error is presented on page 82 and again in appendix B, page 464. The student is not likely to understand from the earlier treatment that this variance arises from two sources: the sampling error in the estimated regression coefficients and the nonzero residual in the prediction period. But this point is made in appendix B. Other measures of accuracy of forecasts are discussed on pages 343–49, and it is here that the author mentions additional sources of prediction errors, such as structural change with the passage of time.

Among the strengths of the book are the excellent examples, including some from agricultural economics, and the good sense of the author. The discussion of multicollinearity is particularly good. The subtlety of the problem and the difficulty of testing for its existence are well illustrated. The discussions of hypothesis testing, though sprinkled throughout the book, also are praiseworthy. For example, Maddala helps set the record straight with respect to the quoting of spurious levels of significance in a final equation after experimentation with the model specification.

A neglected topic, particularly from the viewpoint of agricultural economists, is recursive models. They are mentioned only in one paragraph. An indepth discussion of recursive models might have led the author to draw a different conclusion from one of his examples. In this example (pp. 223f), Maddala wishes to show that the rank as well as the order condition for identifiability should be verified; he argues that one equation in the system is identified by the order condition but not by the rank condition. However, with a suitable rearrangement of the equations, it becomes clear that the parameters of the current endogenous variables form a

triangular matrix. From a causal viewpoint, the system is recursive. Given the assumptions of a recursive model, all of the equations in the system are identified, contrary to Maddala's conclusion.

The art of making judgments about specific problems in empirical econometrics is difficult to convey in writing, but in general Maddala does an excellent job. Of course, since judgment is involved, reasonable persons will not always agree with him. He appears to be predisposed to maximum likelihood estimation whenever feasible, and his interpretation of the evidence on certain issues is occasionally at variance with the interpretation of other, well-known authors. For instance, Maddala writes "It has been found (in some experimental investigations) that the Hildreth-Lu (or the ML) procedure often performs better than the Durbin procedure in estimating the true autocorrelation coefficient" (p. 280). In contrast, Johnston using similar evidence says "the Durbin method . . . is probably better than the others" (p. 265). I found myself agreeing with Maddala far more often than not, and implicit in much of the book is the need to make an informed judgment about a problem rather than following a fixed prescription.

Students of empirical econometrics should be pleased that Maddala has written this book; it will be useful to the novice and to the practicing professional. While the book is not perfect, it meets its principal objective of serving the needs of persons doing applied econometrics. I hope that someday the author will be encouraged to undertake the revisions necessary to make this good book even better.

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Cornell University

Reference

Johnston, J. *Econometric Methods*, 2nd ed. New York: McGraw-Hill Book Co., 1972.

Papageorgiou, George J., ed. *Mathematical Land Use Theory*. Lexington, Mass.: Lexington Books, D. C. Heath Co., 1976, xx + 307 pp., $27.50.

The volume consists of seventeen chapters which are divided into two parts. The first part contains three papers focusing on the general topic of mathematical land use theory. The second contains fourteen separate papers related to specific problems in this field.

The first two general statements, by Britton Harris and by Harry W. Richardson, were initially prepared as position papers for a symposium on mathematical land use theory held at McMaster University in 1975. (This volume grew out of the symposium.) Harris and Richardson focus on the operationality and policy relevance of mathematical land use developments and, more specifically, of the new urban economics (NUE). While both of these papers present a somewhat negative image of the utility of the types of analyses presented in the rest of the volume, Richardson's statements are relatively stronger. Harris states that "perhaps the application of normative models arouses the widest dispute and distrust amongst decision makers and some social scientists" (p. 5). Richardson asserts that the "NUE has no insights—however broad—to offer on [solving the two major planning problems of] predictions of overall urban change . . . and . . . studies of changes in the spatial structure at the intraurban level" (p. 11). He believes NUE models fail on these grounds, "primarily because they do not include time and they trivialize space." The third general introductory paper, by A. Anas and D. S. Dendrinos, however, provides a more optimistic description of the field by providing a detailed review of the state of the art in NUE, and by outlining the existing accomplishments, problems, and issues surrounding the normative models. Anas and Dendrinos' review paper is an excellent introduction to the literature in this field.

The chapters in the second part of the book roughly follow the order of successive development outlined by Anas and Dendrinos, i.e., positive, normative, and dynamic models. The papers by J. Hartwick, U. Schweizer, and P. Varaiga (chapter 4), and by J. R. Miron (chapter 5), are comparative static analyses of the monocentric city, which examine relationships between income classes, land rents, and land consumption and between city size, rent levels, and accessibility. The next four papers deviate from the standard monocentric model with the sharply segregated and noninteracting sets of locators. Tony E. Smith's discussion (chapter 6) serves as an introduction to, and evaluation of, the next three "plasma" type models. John Amson's paper (chapter 7), entitled "A Regional Plasma Theory of Land Use," employs concepts from physics to model urban locational interactions. M. J. Beckmann's contribution (chapter 8) focuses on the spatial interaction of households in a "dispersed" city. The paper by D. R. Capozza (chapter 9) examines relationships between employment and population in different zones (rings) of urban areas. This paper should have more appeal to economists, since Capozza discusses opportunity costs of land for nonresidential uses and employs relatively more economic theory in his analysis.

The papers by G. J. Papageorgiou (chapter 10) and by O. Fisch (chapter 11) examine urban land uses in a spatial equilbrium context. Although the advanced mathematical treatment in these two chapters makes them almost unreadable, they appear to be useful "idea" or background papers for anyone planning a spatial general equilibrium analysis of different land uses. Fisch's treatment of spillover effects (p. 184) may be especially useful in treating questions of the benefits from open-space or greenbelt areas.

Chapters 12 and 13, by N. Alao and D. A. Livesey, respectively, are concerned with optimization and equilibrium models of central business districts (CBD). Alao's concluding remarks about the general benefits of urban places are some of the more thought-provoking in the book. Livesey's comparison of aggregate social profit maximization with aggregate social cost minimization provides a useful discussion of the restrictive features embodied in many of the assumptions employed in CBD models.

The next three chapters depart from the static analysis. D. Pines (chapter 14) examines the optimal spatial pattern of city development within the time dimension. R. F. Muth's paper (chapter 15) is concerned with housing durability in the context of housing production decisions, and with special reference to population density and housing characteristics. Within his analysis of the short-run dynamics in the spatial housing market, A. Anas (chapter 16) also examines influences of differences in expectations of farmers and of the time when they release land to urban development. One major conclusion from these three chapters is that the standard static modeling framework is at a serious disadvantage relative to the dynamic approach which incorporates the concepts of capital durability and the intertemporal nature of private investment and planning decisions.

Relative to the other contributions in this volume, chapter 17, by M. J. Webber stands by itself. Webber's topic is entropy-maximizing models and their relation to economic and urban analysis. He reviews the origins of this field and discusses several misconceptions that have emerged with its use. This chapter should prove to be useful reading for anyone with questions about the use of entropy models in economic analysis.

As with most collections of symposia papers, this volume suffers from a lack of coherency in that the papers did not always follow in a logical order or relate to each other. The introduction by Papageorgiou and Anas, however, did much to overcome this flaw. In fact, one would be well advised to frequently refer back to the introduction for guidance.

Although the central theme of this book is the theory of the NUE, a mathematically prepared reader working other land-use fields may find the papers interesting and, perhaps, suggestive of possible theoretical undertakings. One easily could criticize these papers for a lack of empirical analysis, or even a lack of potential usefulness in empirical forecasting; however, such analyses were not the intent of its authors. As indicated in the title, this is a theoretical treatment of land use. Empirical studies obviously can build upon and test this theory.

This volume should be of interest to that subset of economists working in land-use analysis. A necessary prerequisite to following the various papers, however, is a significant background in mathematics, including such topics as advanced set theory and Hamiltonian functions. It would also be fruitful to read some of the major references discussed in the three introductory chapters before pursuing the rest of the book. Nevertheless, even with these recommended preparations, it is quite possible that one may not find the reading of this volume as the best allocation of scarce reading time.

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Books Received

Aamerine, Maynard A., and Vernon L. Singleton. *Wine: An Introduction.* Berkeley: University of California Press, 1978, xiv + 373 pp., $5.95.

Anderson, Frank R., Allen V. Kneese, Phillip D. Reed, Serge Taylor, and Russ B. Stevenson. *Environmental Improvement Through Economic Incentives.* Baltimore, Md.: Johns Hopkins University Press, 1978, xi + 195 pp., $13.00, $4.50 paper.

Auerbach, Devoira, ed. *Accession List of Regional Plans, Programmes and Projects.* Rehovat, Israel: Settlement Study Centre Project Collection, 1977, iv + 95 pp., price unknown.

Buchanan, James M. *Freedom in Constitutional Contract: Perspectives of a Political Economist.* College Station: Texas A&M University Press, 1977, xii + 311 pp., $13.50.

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Coleman, Gould P., and Jerry D. Stockdale (with Thomas W. Scott and Theodore W. Bateman). *Area Development Through Agricultural Innovation: New York's Sugar Beet Fiasco.* Morgantown: West Virginia University, 1977, 96 pp. monograph, $4.95 single copies.

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Dunlop, John R., and Kenneth J. Fedor, ed. *The Lessons of Wage and Price Controls—The Food Sector.* Cambridge, Mass.: Harvard University Press, 1978, vii + 344 pp., $19.50.

Frank, Charles R., Jr., and Richard C. Webb, eds. *Income Distribution and Growth in Less Developed Countries.* Washington, D.C.: The Brookings Institution, 1977, xiv + 641 pp., $9.95 paper.

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Hassinger, Edward W. *The Rural Component of American Society.* Danville, Ill.: Interstate Publishers, 1978, x + 397 pp., $12.75.

Ingram, James C. *International Economic Problems,* 3rd ed. Somerset, N.J.: John Wiley & Sons, 1978, x + 174 pp., $5.95 paper.

Krishnaswamy, P. B. *Micro-Macro Links in Planning: The Role of Small Group Action in Indian Agricultural Development and Its Implications for Extension.* Canberra: Australian National University, Development Studies Centre, Monograph #9, 1977, ix + 116 pp., $6.00.

Lewis, W. Arthur. *The Evolution of the International Economic Order.* Princeton, N.J.: Princeton University Press, 1978, 81 pp., $7.50, $2.43 paper.

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McHale, John, and Magda Cordell McHale. *Basic Human Needs: A Framework for Action.* New Brunswick, N.J.: Transaction Books, 1978, 249 pp., $5.95 paper.

Meadows, Dennis L, ed. *Alternatives to Growth-1: A Search for Sustainable Futures.* Cambridge, Mass.: Ballinger Publishing Co., 1978, xxvii + 432 pp., $16.50.

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News

Announcements

1978 Meeting Allied Social Sciences Association

The American Agricultural Economics Association and the Econometric Society will meet jointly with the Allied Social Sciences Association 29–31 August, in Chicago, Illinois. Three sessions are scheduled.

Robert L. Thompson will preside over the first session, entitled "International Commodity Markets and Trade." Papers include "The Role of Government Interference in International Commodity Trade Models," by Philip C. Abbott; "The Quantitative Evaluation of Alternative Stabilization Policies in International Commodity Markets," by David Blandford and Seon Lee; and "World Agricultural Trade Models with Imperfect Substitutability," by Paul Johnson, Thomas Grennes, and Marie Thursby.

"Financial Markets for Agriculture" will be led by Peter J. Barry. Papers in this session include "Flow of Funds in Localized Financial Markets," by Michael D. Boehlje and Duane G. Harris; "Incorporation of Investment Decisions and General Economic Outcomes in Econometric Projections Models for Agriculture," by John B. Penson, Jr. and Dean W. Hughes; and "Portfolio Theory and Its Application to Farmer and Lender Behavior," by Lindon J. Robison and John R. Brake.

The final session is "Competition and Regulation in the Food Industry," Leo Polopolus presiding. Allen B. Paul will present a paper entitled "Some Methodological Problems of Research into Competition in Agricultural Markets," and Bruce W. Marion will discuss "Government Regulation of Competition in the Food Industry."

IAEA 1979 Meetings, Banff

The 17th Conference of the International Agricultural Economics Association will be held in Banff, Alberta, 2–12 September 1979. The program theme is "Rural Change: The Challenge for Agriculture."

The conference will look at needs and opportunities ahead and survey its past accomplishments. Plenary sessions, special groups, contributed papers, and discussion groups are planned. Kenneth Farrell, USDA, has announced the contributed paper competition, and William Kibler, USDA, the discussion groups. Glenn Johnson will coordinate the contributed papers with plenary and requested papers.

Murray Hawkins, chairman of local arrangements, has developed a program of social events, short tours, and a wives' program.

Australian Journal Editor Change

J. R. Anderson and J. B. Hardaker are the new editors of the *Australian Journal of Agricultural Economics*, published by the Department of Agricultural Economics and Business Management, The University of New England, Armidale, Australia.

Personnel

University of California, Davis

Leaves: David E. Hansen took a three-month leave of absence as a candidate for congressional office; **Trimble R. Hedges,** emeritus professor, has been awarded a Fulbright lectureship and will spend four months at the University of Sri Lanka, Peradeniya, as a consultant in agricultural economics and animal science extension; **John E. Kushman,** assistant professor, will be on sabbatical leave from 1 October 1978 until 31 March 1979; **Desmond A. Jolly,** extension consumer economist, is on sabbatical at the University of California, Berkeley, through 1978; **Philip L. Martin,** assistant professor, is on leave with The Brookings Institution as a staff associate, until 30 June 1979.
Return: Chester O. McCorkle, Jr. has returned after serving nine years as vice-president of the University of California. He will be on sabbatical leave in residence from 1 October 1978 until 30 June 1979.
Resignation: James G. Youde, extension economist, has accepted a position as director of agricultural projects for the Pacific Northwest Regional Commission, Vancouver, Washington.

Colorado State University

Appointment: George F. Rhodes, formerly at Ohio State University, is associate professor with teaching and research responsibilities in econometrics.

Cornell University

Appointment: Yuzo Yamashita, professor at the University of Tsukuba, Sakamura, Japan, is a visiting fellow.
Resignation: Bert Mason, assistant professor of public affairs management, has accepted a position with Solar Energy Research Institute, Golden, Colorado.

University of Florida

Appointments: Hashim Alwan Al-Samarraie, University of Baghdad, is a visiting post-doctoral fellow; **Richard Clegg Hooks,** formerly assistant in agricultural economics, is assistant in food and resource economics.

Resignation: Chris O. Andrew has accepted a position as assistant director of international programs, IFAS.
Leaves: Charles D. Covey has taken a faculty development leave to study English and Scottish extension services; **Edna T. Loehman** is on leave to conduct economic research in environmental and energy problems at the University of New Mexico.

University of Georgia

Leave: Fred C. White, associate professor, is on leave during 1978 at Virginia Polytechnic Institute and State University.

University of Illinois

Appointment: L. H. Simerl, professor emeritus, is on special assignment with the ESCS, USDA, Washington, D.C., for one year ending in March 1979.

Iowa State University

Appointments: Curtiss D. Huyser and Craig W. O'Riley are research associates, Department of Economics.
Leave: Ronald Raikes, associate professor, is on leave to help with a family farming operation.

Kansas State University

Appointments: Donald B. Erickson is assistant head of extension programs; **Daryl Petty** is an extension economist—farm management (associations), stationed in Holton.

Michigan State University

Leaves: Larry Libby will serve as coordinator for land, air, water, and solid waste programs, USDA Office of Environmental Quality Activities; **George E. Rossmiller** will serve for two years as U.S. Agricultural Attache to OECD, Paris.

University of Nebraska

Appointment: George H. Pfeiffer, Ph.D., formerly research associate, North Dakota State University,

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CED: Commodity Economics Division; **CMPD:** Cooperative Marketing and Purchasing Division; **EDD:** Economic Development Division; **ESCS:** Economics, Statistics, and Cooperatives Service; **FAS:** Foreign Agricultural Service; **FDCD:** Foreign Demand and Competition Division; **NEAD:** National Economic Analysis Division; **NRED:** Natural Resource Economics Division.

is assistant professor in farm and ranch management.
Leave: Dale G. Anderson is visiting professor in the Department of Economics, Kansas State University for one year.

Ohio State University

Appointment: Michael Woolverton, Ph.D. University of Missouri, is assistant professor of agribusiness management.
Retirement: Ralph L. Baker, professor of agricultural marketing and poultry extension economist, retired on 1 April, after 17 years' service.

Purdue University

Appointments: Janet Coapstick is professional assistant, **David C. Lyons** is a swine market analyst, **Stephen Pohl** is a research assistant, and **Margaret O. Saunders,** a visiting assistant professor.
Leave: G. Edward Schuh is on leave as Deputy Assistant Secretary of Agriculture, Washington, D.C.
Return: Joseph B. Goodwin has returned after a three-year tour at Site Lagoas, Minas Geraïs, Brazil.
Resignation: Charles E. French, research coordinator at the Agency for International Development, is now director of the Food and Nutrition Study, President's Reorganization Project.

Rutgers University

Appointments: Daniel Rossi, Ph.D. Pennsylvania State University, and **Ralph T. Schotzko,** Ph.D. Oregon State University, are assistant professors in agricultural business management.

Texas A&M University

Appointment: Ashley Lowell is an area economist-management.
Leave: Dean Ethridge, associate professor, is on a two-year assignment with US-AID in Uruguay.

U.S. Department of Agriculture

Appointments: Marshall R. Godwin, formerly deputy administrator of the Farmers Cooperative Service, is now senior analyst with ESCS administrative staff; **Peter Liapis** joined the Agricultural Resources and Environment Group, NRED, Beltsville, Maryland.
Reassignments: Clifford M. Carman, formerly with NEAD, is now working in the Forecast Support Group, CED, Washington, D.C.; **Walter L. Ferguson,** formerly with NEAD, is now with the Agricultural Resources and Environment Group, NRED; **Jeannette Fitzwilliams,** of EDD's Health and Education Program Area, has been reassigned to the Income Studies Program Area, EDD, Washington, D.C.; and **Dan Williams,** formerly with the director's office, EDD, is now working in the Regional Analysis Program Area.
Resignations: Andrew A. Duymovic, Judith G. Goldrich, and **David M. Schoonover,** of FDCD's Centrally Planned Countries Program Area, have transferred to FAS; **Clarence D. Rogers,** formerly with CED's Fiber and Oils Program Area, Clemson, South Carolina, is now working with the Agricultural Marketing Service, Clemson; **Clement E. Ward,** formerly of CMPD, is associate professor and extension specialist, Oklahoma State University.
Award: Thomas Stinson, EDD, Minnesota, was honored recently for his "sustained outstanding performance and leadership in conducting research on the finance and delivery of community services in nonmetropolitan areas."

Virginia Polytechnic Institute and State University

Appointments: David M. Kohl, formerly at Cornell University, is assistant professor; **Wayne D. Purcell,** formerly at Oklahoma State University, is a professor; and **Peter Vitaliano,** Ph.D. University of Wisconsin, is assistant professor.

Washington State University

Appointment: Hans Radtke, formerly at the University of Nevada, is extension marine resource specialist.
Return: James C. Barron has returned from a two-year assignment in Ghana.

Other Appointments

Charles T. Alexander, Jr., M.S. University of Missouri, is an economic analysis advisor to Agricultural Cooperative Development International, the National Milling Corporation, Tanzania.
Walter J. Armbruster has been named the associate managing director of Farm Foundation, Oak Brook, Illinois. He was formerly a staff economist, Agricultural Marketing Service, USDA.
A. John DeBoer, formerly at the University of Queensland, Australia, is an economist, Agro-Economic Division, International Fertilizer Development Center, Muscle Shoals, Alabama.
Tesfaye Gebremeskel, Ph.D. Texas A&M University, is an assistant professor, School of Business, Texas Southern University.

Donald Harrington, M.S. University of Missouri, is a Peace Corps volunteer in Kenya.

Donna Elaine Hauser, M.S. University of Missouri, is a Peace Corps volunteer in Paraguay.

Kenneth Roberts, M.S. University of Missouri, is a Peace Corps volunteer in Paraguay.

James R. Wilson, Jr., M.S. Virginia Polytechnic Institute and State University, is a research associate in the Department of Economics, University of Alaska.

James H. Wilson, M.S. Virginia Polytechnic Institute and State University, is a commodity analyst, FAS USDA.

Obituaries

Lyle Harris Barnes

Lyle Harris Barnes, professor emeritus, Department of Agricultural Economics and Rural Sociology, Ohio State University, died on 25 December 1977.

Barnes was born 31 December 1896 near Morrow, Indiana. He graduated from Kawanna, Indiana, High School in 1914, attended Valparaiso Business College, and graduated from Purdue University with a B.S. degree in agriculture in 1920. He served with the United States Navy during World War I.

Barnes farmed with his father in Gladwin County, Michigan, for one year prior to serving as a county agent in Scott and Lake Counties, Indiana, from 1920 to 1924. In 1924 he was appointed county agricultural extension agent for Lake County, Ohio. He transferred to Medina County in 1926 and served there until 1928.

He joined the Department of Rural Economics, Ohio State University, in 1928 and retired 31 December 1961. As farm management specialist, he was a respected agricultural leader. He was dedicated to his family, community, profession, and church. He will be remembered for his outstanding contribution in representing Ohio State University to the people of Ohio.

Barnes is survived by his wife, Helen, daughter, Lois, and sons, Bruce and Josh.

Raymond O. Gaarder

Raymond Olaf Gaarder was born in Roundup, Montana, 30 December 1922, and died at Pierre, South Dakota, 27 March 1977.

Gaarder graduated from Blythedale, Missouri, High School in 1940, and received his B.S. degree from the University of Missouri in 1949. He received a M.S. degree from Texas A&M University in 1950, and a Ph.D. degree in agricultural economics from Iowa State University in 1962. Since then he has held various positions in economics and argicultural marketing with the U.S. Department of Agriculture, the National Livestock Producers' Association, and South Dakota State University. He was an associate professor of economics at South Dakota State University 1969–72, leaving there to serve as planning officer for the Tanzanian Livestock Marketing Company in Africa. He joined the South Dakota Department of Agriculture in 1974.

In 1976 he took leave to serve as a livestock marketing consultant to the Kenyan government in Africa, and, while there, assisted in establishing export contacts for South Dakota among various African and European nations.

At the time of his death, Gaarder was marketing specialist and economist for the Division of Marketing and Agricultural Development of the State Department of Agriculture, Pierre, South Dakota. He was known for his work in initiating the Department's Grain Market News Program and the Beef Carcass Data Service.

Gaarder is survived by his wife, Ferne, of Pierre, South Dakota, three sons, and one daughter.

Aden Combs Magee

Aden Combs Magee died 27 March 1978, in Bryan, Texas. He retired as professor of agricultural economics at Texas A&M University in 1968, after 38 years of service with that institution.

Magee was born in Langford, Kansas, in 1888, and received his undergraduate degree from Kansas State University and a masters degree from Texas A&M University. He was a ranch manager and then served with the Texas Extension Service four years before joining the Texas A&M agricultural economics faculty in 1931. He was chief of party of Texas A&M University US-AID projects in both Argentina, 1964–66, and the Dominican Republic, 1966–68.

He is survived by his widow, Grace, three married sons, and six grandchildren.

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—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
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